ECONOMIC ZOOLOGY AND ENTOMOLOGY

KELLOGG AND DOANE

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BY THE SAME AUTHORS

BY VERNON LYMAN KELLOGG

ELEMENTARY ZOOLOGY
Pp. xv + 492, 172 figs., 12mo, 1901.

FIRST LESSONS IN ZOOLOGY
Pp. x + 363, 257 figs., 12mo, 1903.

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Pp. vii + 671, 812 figs., 11 colored plates, 8vo, 1905 (American Nature Series, Group I), Students' Edition.

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INSECT STORIES
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THE ANIMALS AND MAN
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INSECTS AND DISEASE
Pp. xiv + 227, illustrated, 1910 (American Nature Series, Group IV).

Development of young king salmon. The first figure shows egg just after fertilization; second, the egg 30 days later; third, the egg 60 days later. The fourth figure shows the young salmon just after hatching; the others show the development at the end of each month, the largest fish being 8 months old. (About two-thirds natural size.)

ELEMENTARY TEXTBOOK OF

ECONOMIC ZOOLOGY

AND

ENTOMOLOGY

BY

VERNON LYMAN KELLOGG

PROFESSOR OF ENTOMOLOGY AND LECTURER IN BIONOMICS
IN STANFORD UNIVERSITY

AND

RENNIE WILBUR DOANE

ASSISTANT PROFESSOR OF ECONOMIC ENTOMOLOGY
IN STANFORD UNIVERSITY

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PREFATORY NOTE

The point of view from which this book is written is explained in its first chapter. For that matter it is indicated clearly by the title. If the study of zoology is being neglected in schools for the alleged reason that it is not a useful study, the neglect is based on an unsound reason. For zoology is useful, and not in one way alone, but in two ways; and both of these in addition to its pedagogic value as a study which develops accurate personal observation and independent personal attainment of conclusion.

Zoology is first of all useful in the way so often stressed by Huxley, as a study that gives us a sounder basis for our own life by showing the demands of Nature on animal life in general and the kinds of responses to be made to these demands. In other words it is quite specially a branch of science that can help us largely as a guide to living in conformity to natural laws. Zoology is also useful in a more obvious and commercially ratable way, by revealing the precise relation which many animals bear to us in their attitude of friends to be cultivated, or foes to be fought. Injurious insects, alone, cause this country an annual loss of a billion dollars. A general knowledge of insect life and an intelligent and vigorous application of this knowledge can save the nation half this loss.

To the teacher intending to use this book as class guide there is due a word of explanation. The authors have attempted to make the book an introduction to general zoology as well as to that specific phase of it called economic. The first chapters are therefore of a nature to introduce pupils to general facts of animal structure and life. They are arranged on the basis of accepted pedagogic principles. The later chapters, arranged on a basis of animal classification, proceeding from the simpler to the more highly developed groups, include not only general facts

pertaining to the groups treated, but introduce and give special attention to the economic relations of various particular members of the groups. Finally in still later chapters, segregated in a separate section of the book, there is presented a sort of encyclopedic treatment of a considerable body of facts wholly economic in aspect. These chapters are to be used as reference matter, collateral reading, and matter to suggest practical work, rather than as material for recitation. Of the numerous insect kinds treated in the chapters on injurious insects, only a certain few will be found in any single region. Those few are the ones intended for study by pupils in that region. The study should be mostly field work.

We wish to thank Professor Harold Heath for his kindly critical reading of much of the manuscript of the book. The sources of such illustrations as are not original with us are pointed out in the subscriptions to the figures. We owe thanks to many friends in this connection.

V. L. K.
R. W. D.

Stanford University, California,
December, 1914.

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ECONOMIC ZOOLOGY AND ENTOMOLOGY

PART I

CHAPTER I

ANIMALS, AND THE STUDY OF ANIMALS

Many books about animals begin with a definition of an animal. As a matter of fact animals cannot be precisely defined. At the bottom of the animal scale are many very small, very simple creatures that are so like certain other very small and very simple creatures which are usually classified as plants, that one cannot state in precise words just what distinguishes the so-called animals from the so-called plants. But the experience that everyone of us has from knowing dogs, horses, birds and butterflies, and trees, bushes, flowers and weeds, will serve to make us recognize the major and usual distinctions between most animals and plants. The free locomotion, the sense organs, nervous system and sensitiveness, the need of already living or once living substances for food, the large intake of oxygen and out-pouring of carbon dioxide of most animals, contrasted with the fixity, the lack of sense organs and nervous system, the use of inorganic substances for food, and the large intake of carbon dioxide and outpouring of oxygen of most plants, are distinctions made familiar by our common experiences.

This common observation and experience enables us, also, to distinguish with practical certainty between all living and all non-living things, although the modern study of biology is moving along lines that make it more and more nearly impossible to tell accurately in words just what distinguishes so-called living or organic nature from so-called non-living or inorganic nature. In fact almost the only remaining positive criterion of living matter is the inevitable presence in it of certain complex chemical compounds called proteins. These

are wholly wanting in inorganic matter. Practically none of the other distinctions usually given will stand close scrutiny and critical analysis.

A recent estimate by a reliable naturalist of the number of known kinds of animals puts this number at 522,400. It is quite certain that there are as many more not yet known. Of these million living animal kinds each of us knows but few, some of us very few indeed. And these few we usually know most superficially; usually only their general external appearance and a little about their habits. Yet this little that we know about animals is sufficient to serve as an introduction to the science of zoology, if we will think seriously of it and try to arrange it in some orderly or classified way. That indeed is what the whole science of zoology is; an orderly arrangement of all the known facts about animals.

This arrangement usually begins by a grouping of the facts under five principal heads. These are animal classification, or systematic zoology; animal morphology, or structural zoology; animal physiology, or functional zoology; animal embryology and life-history, or developmental zoology; and animal relations to their environment, or ecological zoology. Animal psychology or behavior is also sometimes made a special head in the classifying of zoological facts, but it may better be included in the subject of animal physiology.

No one elementary text-book can deal in a comprehensive way with all of these phases of the study of animals. And yet no one phase can be satisfactorily studied wholly by itself. The classifying of animals into related groups depends upon a knowledge of animal structure and development. To understand animal structure one must know something of animal physiology, and *vice versa*. Finally, to understand the relations of animals to the world they live in, to the plants that serve them as food and protection, to the other animals that they associate with as friends or enemies, and to man, whose relations with them are much more complex and important than we may, at first, think, it is absolutely necessary to know something about all the other subjects of animal study.

This book, therefore, which is intended to guide students

who wish to learn about animals from the special point of view of their interrelations with man, that is, their possible use and hurtfulness and even danger to us, and our possible power to develop this use and minimize this injury, will be found not to neglect those other phases of animal study which are indicated under the titles of classification, morphology, physiology, and development.

But no text-book of zoology can really give the student the knowledge he seeks. He must find out most of it for himself, especially if he wants it to stick. A text-book based on the experience of others is chiefly valuable for suggesting to him how to work most effectively to get the knowledge for himself. And the best students always find out things which are not in books.

CHAPTER II

A STUDY OF THE FROG

Before beginning a discussion of the animal kingdom as a whole, or of any of the important groups into which it is divided a few animals representing different conditions of bodily make-up may be studied. The student will then have some definite, first-hand knowledge of the structure and organization of animals.

FIG. 1.—A common western frog, *Rana boyli.*

A frog or a common garden toad, may be used as a type of a vertebrate animal, that is, one with a backbone. Except during the cold winter months frogs may usually be found around ponds or along the banks of streams. In the spring and early summer toads, too, are common around the water where they are breeding. Later in the summer toads may be found in almost any garden, where they can best be collected at dusk.

Whenever possible the whole class should join in collecting the material in order that all may see the animal in its usual haunts and study its habits there. Living specimens may be kept in the laboratory for some weeks during which time many interesting observations may be made. But in order to make a closer study of the structure of the animal it must be killed. This may be done by placing the frog in an air-tight jar or other vessel with a piece of cotton or cloth that has been saturated with chloroform or ether. The following description is written for the frog, but it will serve also as a guide for the study of the toad, as the two animals are alike in general structure.

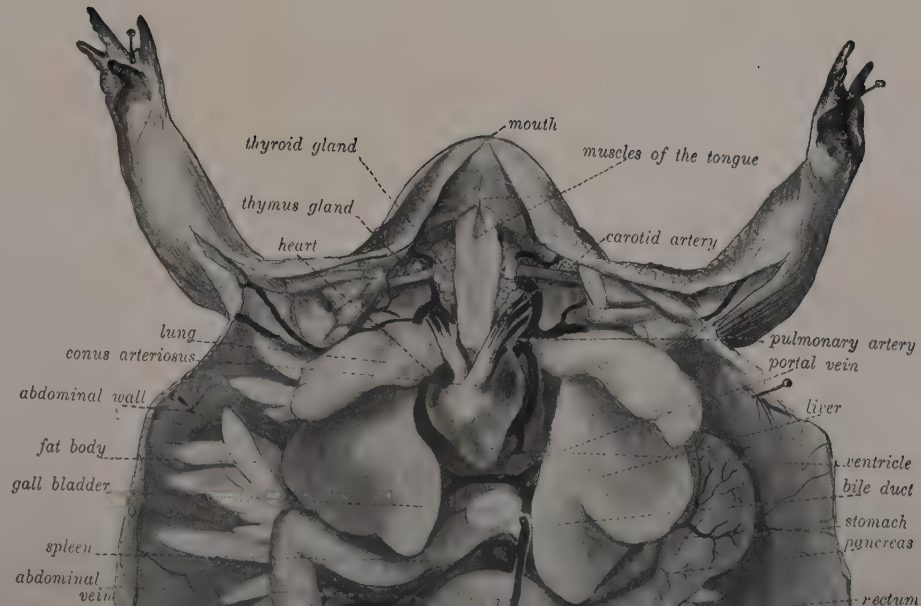
External Structure.—The body of the frog is divided into two principal regions, the *head* and the *trunk*. In most vertebrates there is a distinct neck between these two regions, but in the frog they are closely united. The forelegs, or arms, are well developed, but the hind legs are much longer and stronger, enabling the animal to leap for considerable distances. On the hands are four fingers or *digits* and a rudiment of a thumb. The five toes on the hind legs are connected by a web.

The tough skin that covers the body is kept moist by the secretions from many glands. The eyes are large, prominent and protruding. When they are closed they are drawn back into their orbits somewhat and covered mostly by the lower eyelid, which is thin and freely movable. The upper eyelid is thick and not capable of much movement. The *tympanum*, the outer membrane of the auditory organ, is a smooth elliptical membrane just back of each eye. When sound waves strike the tympanum, causing it to vibrate, the vibrations are transferred to the inner ear by a minute rod, the *columella*, which extends between the two. The nostrils are in front of the eyes and above the mouth. The wide mouth extends from one side of the head to the other. In the frog there are a few small teeth on the upper jaw and in the roof of the mouth which serve only to hold the prey. No such teeth are present in the toad. The tongue is attached by its anterior end. The posterior end is free and can be extended forward out of the mouth nearly its full length for capturing insects. As the tongue is covered with a mucous secretion the insects stick to it and are quickly

drawn into the mouth. In the roof of the mouth are two pairs of openings. The anterior pair, the *inner nares*, are the internal openings to the nose; the posterior pair, just posterior to the eyeballs, are the internal openings to the wide *Eustachian tubes* which lead to the mouth from the chamber of the ear behind the tympanum. At the posterior end of the mouth is the opening of the esophagus through which the food passes into the stomach. Just below the opening of the esophagus is a perpendicular slit-like opening, the *glottis*. This opens into the short *larynx* through which the air passes to the lungs. The flaps just within this opening are the *vocal cords*.

Internal Structure.—In making the dissection for the study of the internal structure it is best to make the cut along the ventral side from the anal opening, at the posterior end of the body, to the angle of the lower jaw. The first cut should be made only through the skin in order to expose some of the muscles that control the movements of the body. The large sheet of abdominal muscles covering the ventral side of the frog consists of two sets, an outer and an inner layer. Posteriorly they are attached to the bony pelvic girdle which supports the hind legs. The size, position and points of attachment of the heavy bundles of muscles that control the leg movements should also be noted.

The incision may then be made through the body-wall, and the sides fastened back to expose the internal organs. The digestive system may be studied first. The esophagus, as we have noted, leads from the opening at the back of the mouth to the stomach. The stomach is somewhat crescent-shaped, and lies mostly on the left side of the body. The anterior, or *cardiac*, end is larger than the posterior, or *pyloric*, end where it joins the small intestine. The *small intestine* is a long coiled tube opening into the *large intestine* or *rectum*. The posterior part of the rectum is known as the *cloaca*, for it also receives the waste products from the bladder and kidneys. The *ova* and *spermatozoa* also pass from the body through the cloaca. The reddish-brown lobes of the ***liver*** are conspicuous. They secrete the bile, which is an alkaline fluid that aids in digestion. The *gall-bladder*, where the bile is stored, lies between the lobes


mouth
thyroid gland
muscles of the tongue
thymus gland
carotid artery
heart
lung
pulmonary artery
conus arteriosus
portal vein
abdominal wall
liver
fat body
ventricle
gall bladder
bile duct
stomach
spleen
pancreas
abdominal
rectum

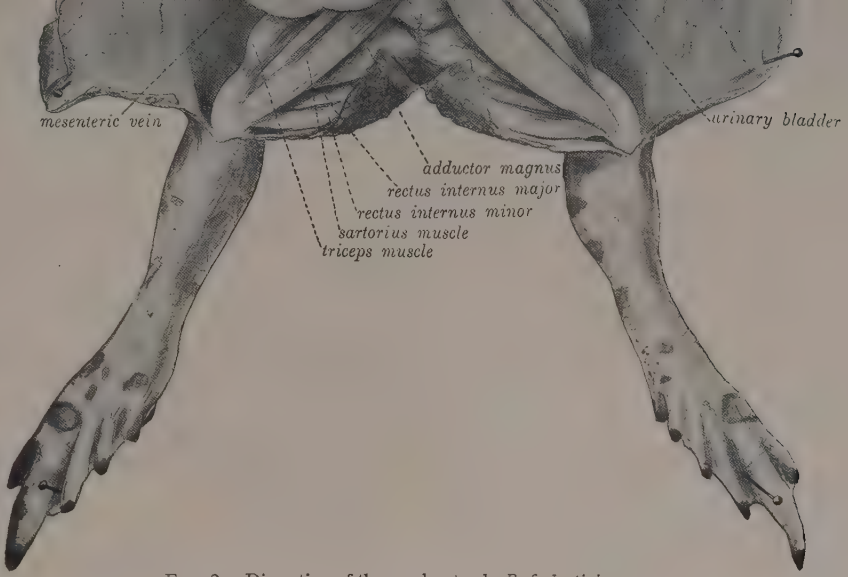


FIG. 2.—Dissection of the garden toad, *Bufo lentiginosus*.

of the liver and opens into the *duodenum*, the first part of the small intestine, through the bile duct. The pinkish, many-lobed *pancreas* lies between the duodenum and the stomach. It also secretes a digestive fluid which is poured into the duodenum through the common bile duct. The food, which consists chiefly of insects and worms, is first acted on by the fluid secreted by the mucous layer of tissue lining the esophagus. As it passes into the stomach the acid gastric juice that is secreted by the walls of the stomach also acts upon it and digests out some of the proteid matter. In the duodenum the bile and the pancreatic juice act upon the fats and starches. The food, thus digested and made available, is taken up by the walls of the intestine and carried by the blood and lymph to all parts of the body to build up new tissue and increase the size of the body, or to renew tissue which has been worn out by the various activities of the animal. Some reserve food is stored in the liver in a form that is available for use when necessary, as during the winter while the frog is hibernating. Nutriment is also stored in the large many-branched yellowish *fat bodies* which are closely connected with the reproductive organs.

The *lungs* are thin-walled, sac-like bodies. The area of the inner surface is increased by many folds which form minute spaces, the *alveoli*, the walls of which are abundantly supplied with blood capillaries. The waste carbon dioxide in the blood is given off and the oxygen taken up through the thin walls of these capillaries. The air passes through the nostrils or external nares into a slightly enlarged chamber, the *olfactory chamber*, thence through the posteror nares into the mouth. The nostrils are then closed, the floor of the mouth is raised, and the air is forced through the glottis into the short larynx and into the lungs. The air is forced out from the lungs by the contraction of the muscles of the body-wall. While respiration is carried on chiefly by the lungs, the skin, particularly in the frog, acts in the same capacity, the transfer of gases taking place through the capillaries there as in the lungs.

The Circulatory System.—The blood of the frog is a liquid *plasma* which contains three kinds of corpuscles. The comparatively large, flattened, elliptical, red corpuscles are most

numerous and give the red color to the blood. They contain a substance called *hemoglobin*, which takes up the oxygen in the respiratory organs and carries it to the other tissues of the body. The white corpuscles, or *leucocytes*, are amœboid in character, and are able to change their shape and move about independently. It is their duty to take up and destroy any small foreign objects such as bacteria, parasitic germs, bits of broken-down tissue, or other particles that should be eliminated. In this way they prevent the undue multiplication of many disease germs that might prove most serious if they attained to considerable numbers. The *spindle-cells* are corpuscles which may later develop into red corpuscles. Most of the blood corpuscles are developed in the marrow of the bones, although many of the white corpuscles are formed in the *spleen*, which is a reddish, oval body lying above the anterior end of the cloaca. The blood is contained in a system of veins and arteries with a central pumping station, the *heart*, which drives the blood out through the blood-vessels to all parts of the body. With the aid of a microscope the blood may plainly be seen circulating through the membrane between a live frog's toes. Besides the red blood in the closed circulation, there is a colorless *lymph* containing white corpuscles occurring in many *lymph spaces* in various parts of the body. The lymph is derived from the plasma of the blood and ultimately flows back into the veins. The lymph spaces connect with each other, and the large *lymph hearts* in the dorsal part of the body cavity, by their pulsations, drive the blood into two of the veins in the region of the heart.

The pear-shaped heart is enclosed in a delicate semi-transparent sac, the *pericardium*. It is made up of the conical muscular *ventricle* and the thinner-walled *right* and *left auricles*. When the ventricle contracts, the blood is driven out through the thick-walled *truncus arteriosus*, which soon divides. Each of the divisions gives off three branches, the *carotid arteries*, which supply the head, the *systemic arteries*, which pass around the alimentary canal and unite above forming the *dorsal aorta*, and the *pulmonary arteries*, which carry blood to the lungs and the skin. The systemic arteries and the aorta give off branches

which carry blood to the greater part of the body and to the viscera. The pulmonary arteries, or *pulmo-cutaneous arteries* as they are sometimes called, divide just before they reach the lung, one branch passing out to the skin.

The arteries entering the lungs at once divide into smaller and smaller vessels and finally into the small capillaries where, as already said, the blood is purified by giving off its carbon dioxide and taking up oxygen. The capillaries collect again into larger and larger *veins* and the blood is returned from the lung to the left auricle of the heart through the *pulmonary vein*. All of the arteries that pass out to the various parts of the body also divide into smaller and smaller vessels and into capillaries which in turn unite to form veins. Some of the veins carry blood through the *kidneys*, where urea and other waste matter is taken out; others carry blood to the liver; but all of the veins from the different parts of the body finally unite into three large veins which open into the *sinus venosus*, a thin-walled sac on the dorsal side of the heart. From the sinus venosus the blood enters the right auricle. The right auricle thus becomes filled with the impure blood, that is, with blood that has given up its oxygen to the tissues in all parts of the body and is carrying carbon dioxide as waste. The left auricle, as we have seen, is filled with blood that has just returned from the lungs and the skin, hence it is pure, that is, it contains much oxygen and no carbon dioxide. The two auricles contract simultaneously and send the blood into the ventricle, that from the right auricle into the right side of the ventricle, that from the left auricle into the left side. When the ventricle contracts the impure blood in the right side is forced out first and passes into the pulmonary arteries, and the blood in the left side, which has already received its oxygen, is sent out through the carotid and systemic arteries, carrying its oxygen and nourishment to all parts of the body. A longitudinal section through the heart and the beginnings of the arteries will show the valves that keep the blood from flowing back when the heart contracts.

The Excretory System. The reddish glandular *kidneys* lie close to the dorsal body-wall. They are composed of connec-

tive tissue in which are series of small tubules that take out much of the waste material from the blood that flows through the kidneys. This waste material, *urea*, passes from the kidneys through the *ureters* into the cloaca and collects in the sac-like *bladder*, from which it is finally expelled through the anus. The skin, liver and the walls of the intestines take some part in excretion, but the kidneys are the principal excretory organs. By the side of the kidneys are the yellowish *adrenal bodies*.

In the region of the kidneys may be seen the *reproductive* organs. In the female the *ovaries*, when filled with the small black and white eggs, are very conspicuous. As these eggs develop they break out into the body-cavity and find their way into the open ends of the long convoluted *oviducts*. While passing through the oviduct the eggs receive a coating of an albuminous fluid which swells up when it reaches the water. The eggs are collected in the posterior portion of the oviducts and finally pass into the cloaca and out of the body. The white ovoid *testes* of the male are attached to the ventral side of the kidneys by folds of the *peritoneum*, which is a membrane lining the abdominal wall. From each testis a number of delicate tubes, called *vasa deferentia*, enter the kidney and become connected with the urinary tubules. The spermatozoa that are developed in the testes thus pass through the kidneys and the ureters into the cloaca. The eggs are fertilized by the spermatozoa which is poured over them while the female is laying them.

The Skeleton.—The bones making up the skeleton of the frog may be considered in two groups: the *axial skeleton* made up of the *skull* and the *vertebral column*, and the *appendicular skeleton* consisting of the bones of the fore and hind limbs and the *pectoral* and *pelvic girdles*. The skull consists of the bones forming the immovable upper jaw, the movable lower jaw, the *hyoid apparatus* supporting the tongue, and a number of bones joined together to form the narrow *brain case*. The vertebral column is made up of nine *vertebræ* followed by a slender bony rod, the *urostyle*. Each vertebra consists of lateral *transverse processes* and a firm central portion which surrounds the *neural*

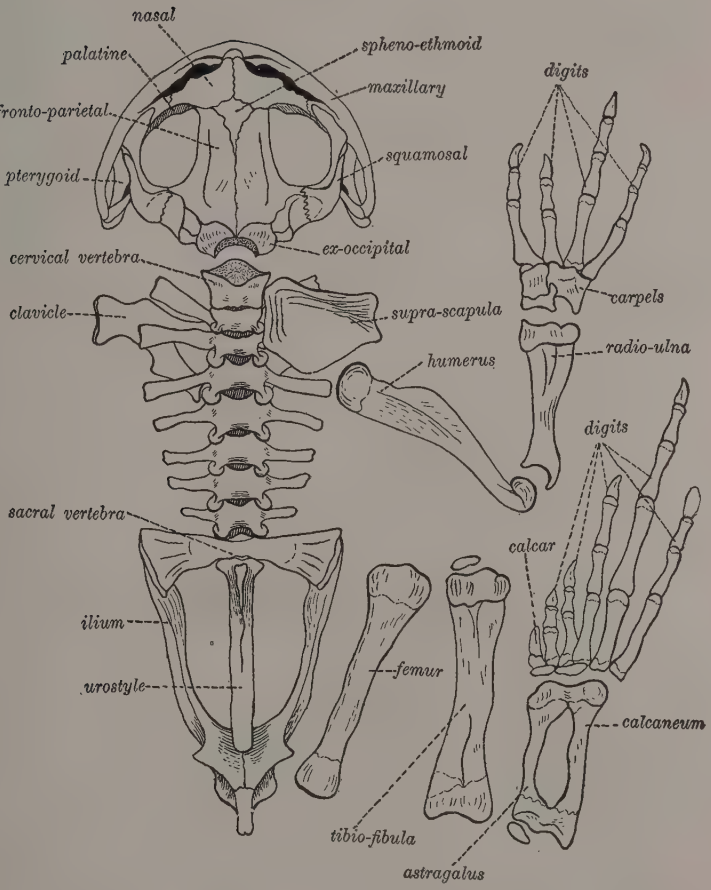


FIG. 3.—Skeleton of garden toad.

canal. The pectoral girdle, which supports the fore limbs and protects the organs in the anterior part of the body, is composed of several bony or cartilaginous pieces. The large flat *suprascapula* lies above the vertebral column; the *scapula*, *clavicle* and *coracoid* pass downward on either side and connect with the *sternal bones* in the median line. The large *humerus* of the arm is attached to the pectoral girdle between the scapula and coracoid. The forearm consists of the fused radius and ulna, the *radio-ulna*. The wrist contains six small *carpal* bones. In the hand are the five basal *metacarpal* bones, and beyond them the *phalanges*, two each in the second and third digits and three in the fourth and fifth digits. The pelvic girdle is shaped somewhat like the "wish-bone" in fowls, the long bone, the *ilium*, on each side connecting with the transverse process of the ninth vertebra. The bones of the hind limb consist of the *femur*, *tibia-fibula*, four small *tarsal* bones, the *astragalus* and *calcaneum*, the *digital bones*, consisting of the *metatarsals* and the *phalanges*, and the small *calcar*, or *prehallux*.

The Nervous System.—The nervous system can best be dissected out in specimens that have been macerated in 20 per cent. nitric acid for some time. The brain consists of the two large fused *olfactory lobes*, the elongated *cerebral hemispheres*, the rounded *optic lobes*, the small *cerebellum* and the long *medulla oblongata* which gradually narrows into the spinal cord. The *optic chiasma*, the *infundibulum* and the *hypophysis* are on the ventral side. The *spinal cord* extends through the neural canal in all the vertebræ and ends in the urostyle. The brain and spinal cord give off many large nerves which branch and subdivide and finally reach all the tissues of the body. The *sympathetic system* consists of two principal nerve trunks, one on each side of the vertebral column, and a series of nerves which are distributed to the internal organs.

Life History and Habits.—In the spring the frog lays her eggs in masses in the water of ponds or ditches. The gelatinous substance which surrounds them soon swells so that the egg-mass looks like a ball made up of little round bits of jelly with black centers. The toad's eggs are similar to the frog's

eggs, but are laid in strings instead of in masses. The young tadpoles which hatch from these eggs look more like fish than frogs. The body is long and ends in a long fin-like, flattened tail. No legs are present, and the animal breathes by means of two pairs of external gills. As the tadpoles grow and develop first the hind legs and then the forelegs begin to appear, lungs develop and the gills disappear, and the tail shortens and finally disappears. The animal is now frog-like, though still very small. Further growth is very slow and frogs are not really adult, that is capable of producing young, until they are two or three years old or older.

The tadpoles feed upon vegetable matter and minute animals that they find in the water. The adults feed principally on insects and worms, the toads especially destroying many insects during the warm summer nights. As most of these insects are sure to be injurious to some of the garden crops the toads are to be regarded as great friends of the horticulturist, and every effort should be made to keep them in the garden. As a result of a series of studies on the habits of the common toad it has been estimated that a toad in a garden may be worth nearly $20 in a single season. As they may live for ten years or longer they are truly valuable assets of the gardener.

Toads and frogs have many enemies, among the most important of which are snakes and some of the shore birds. From some of these enemies they have little or no protection save their nocturnal habits and their ability to dive deep into the water when alarmed. The milky fluid which is secreted by ertain glands in the skin protects them from some animals which might otherwise be important enemies. There is no foundation for the belief that the toad will cause warts to appear on the hands of a person handling it, nor for many of the other curious superstitions concerning this perfectly harmless little animal.

CHAPTER III

A STUDY OF THE GRASSHOPPER

As grasshoppers, or locusts, are among our most common animals, one of these may be taken as a representative of the great group of invertebrates, or animals without a backbone.

When collecting specimens for this study both winged and wingless, or apparently wingless, individuals may be found. This depends on the fact that when young grasshoppers issue from the eggs they look much like the adults, but are without

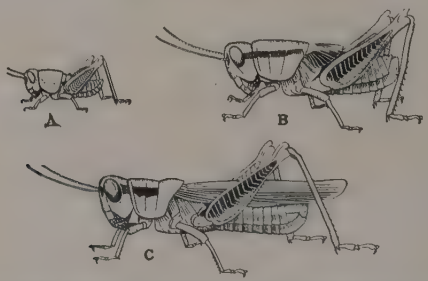


FIG. 4.—Three different stages of a locust, *Melanoplus femur-rubrum*; *a*, just hatched, without wing-pads; *b*, a later stage showing wings beginning to develop; *c*, adult, with fully developed wings.

wings, and the head and hind legs are often abnormally large. As the insects pass through the successive stages of growth, rudimentary wings appear. These increase in size from time to time until the adult condition is reached.

Division of the Body into Regions.—The body is divided into three well-defined regions, the *head* with its eyes, *antennæ* (feelers) and mouth-parts, the *thorax*, which bears the two pairs of wings and the three pairs of legs, and the *abdomen*, which

is composed of a series of more or less similar body rings or segments.

The Body-wall.—Some parts of the skin or outer body-wall are quite firm and horny in texture, others are more parchment-like, and there are still other places in it, such as the neck and between the segments of the legs and the segments of the abdomen, where the skin is soft and flexible. These differences are due to the fact that a horny substance called *chitin* is abundantly deposited in parts of the skin thus

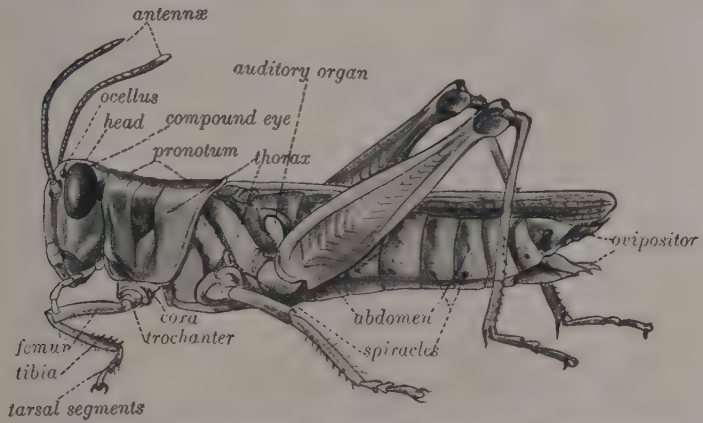


FIG. 5.—The red-legged locust, *Melanoplus femur-rubrum*, to show external structure.

making it firm for the protection of the internal organs, and for the attachment of muscles. Wherever motion or the bending of the body-wall is desirable, little or no chitin is deposited. The chitinized portions of a segment are called *sclerites*. The furrows or lines between the sclerites are called *sutures*.

The Head.—Although the head is apparently a single segment, it is really composed of several body segments greatly modified and firmly fused together, making a strong box which contains what may, by analogy, be called the brain, and certain other important organs. On each side of the head are the large

conspicuous *compound eyes*. These eyes are called compound because they are made up of a great number of small eyes lying very close together. Examined with a hand lens or the low power of a microscope the compound eyes show a honeycomb-like structure, each of the small hexagonal facets being the external surface of a simple eye. In slight depressions just in front of the eyes are the bases of the long, many-segmented *antennæ*. These antennæ are sense organs and are used by the locust for feeling and perhaps also for smelling. In many other insects they are modified and plainly used for smelling and also, in some, for hearing. In the middle of the front of the head, a little lower than the bases of the antennæ, is a small transparent hemispherical simple eye or *ocellus*. Just above the bases of the antennæ and close to the compound eyes are two other simple eyes. The structure and function of these three ocelli as well as the structure of the compound eye is discussed in Chapter XVI. On the lower side of the head are the mouth-parts. The upper, broad, flap-like piece, the *labrum*, covers a pair of black or brown, strongly chitinized, toothed jaws, or *mandibles*. Back of the mandibles is a second pair of jaw-like structures, the *maxillæ*, each of which is composed of several parts, and back of the maxillæ is the *labium* which is also composed of several pieces. Each maxilla bears a slender feeler, or *palpus*, composed of five segments. The labium bears a pair of similar palpi, which are, however, only three-segmented. The mandibles and maxillæ, which are the insect's jaws, move laterally, not vertically, as with most animals. They are well adapted for tearing and crushing the leaves or other plant tissue upon which the locust feeds. Some other kinds of insects will be found to have these mouth-parts curiously modified, enabling them to pierce the animal or vegetable tissues on which they are feeding or to lap up or suck up liquid substances.

The Thorax.—The thorax is composed of three segments which can be easily recognized by the appendages which they bear. The first segment, the *prothorax*, is freely movable and is covered by a large hood-shaped piece, the *pronotum*, which also extends back over the next segment. The first pair of

legs is attached to this segment. Between the forelegs there is, on many species of grasshoppers, a short, blunt tubercle. The second and third segments, the *mesothorax* and the *metathorax*, are immovably fused, but their borders are indicated by well-marked sutures. There is also on the side of each segment a suture near the middle which divides the sides of the segments into two sclerites. The mesothorax bears the second pair of legs, which are similar to the first pair, and the first pair of wings. The metathorax bears the large, third pair of legs and the second pair of wings.

Each leg is composed of several successive parts or segments. The segment nearest the body is sub-globular and is called the *coxa;* the second segment is smaller than the coxa and is called the *trochanter;* the third, the largest, is the *femur;* the fourth, the *tibia*, is long and slender; the three short segments beyond the tibia are called the *tarsal* segments. The terminal segment, which is longer and more slender than the others, bears a pair of claws, between which is a little pad, the *pulvillus*. The tibiæ are armed with small spines, and the femora of the last pair of legs are enormously developed, enabling the insect to leap some distance. Just above the base of each of the middle pair of legs is a small, slit-like opening, or *spiracle*, guarded by two fleshy lips. These spiracles are the external openings of a set of fine tubes forming the respiratory system, which as we shall see, carries air to all parts of the body.

The front wings are long, narrow and parchment-like, with branched and unbranched longitudinal veins and many short cross-veins. The hind wings are triangular in outline, membranous, and when at rest are folded like a fan. Some of the veins at the base of each pair of wings are thickened and raised or depressed in such a way that they set the wings to vibrating rapidly when they are rubbed together. This produces the crackling sound sometimes heard when grasshoppers are flying. A somewhat similar sound is produced when the insect, at rest, rubs the roughened inner surface of the hind femora against the outer pair of wings.

Abdomen.—The first segment of the abdomen has its upper, or *dorsal*, and lower, or *ventral*, parts widely separated by the

cavities for the insertion of the hindmost legs. The ventral part of this segment is dovetailed into the ventral part of the metathorax and appears to be a part of it. In the lower angle of the dorsal part there is on each side a large opening, the external opening of the auditory organ. The thin membranes within these openings are the *tympana*. The crickets and katydids have similar auditory organs situated in the tibiæ of the front legs. Most other insects are believed to have the sense of hearing situated in the antennæ. The second to the eighth abdominal segments are ring-like and similar. Close to the anterior margin of each segment just above the lateral line is a small spiracle similar to the one on the mesothorax but much smaller. The first abdominal spiracles are on the first segment just in front of the auditory organs. The terminal segments of the abdomen are different in the male and female. The female has at the tip of its abdomen two pairs of strong, curved, pointed pieces which compose the *ovipositor*, or egg-laying organ. By alternately bringing together and separating the two pairs of processes that form the ovipositor and at the same time pushing the abdomen into the ground the female is able to make a deep hole in which she deposits her eggs. The end of the abdomen of the male is rounded and has three short inconspicuous pieces on the dorsal surface.

Internal Anatomy

By carefully cutting away one side of the body-wall most of the internal organs will be exposed. The *alimentary canal* occupies the greater part of the body-cavity. Its different divisions, such as the short *esophagus* leading from the mouth to the much enlarged *crop* which extends through the thorax to the *stomach*, may be easily distinguished. The stomach extends to about the seventh segment of the abdomen and ends in the *large intestine*. The *small intestine* is a short tube running from the end of the large intestine to the anal opening at the end of the body. The *gastric cæca* are a series of pouch-like organs which open at the union of the crop and the stom-

ach. They secrete a fluid which aids in digestion. The *Malpighian tubules* are a number of fine hair-like tubes which arise from the alimentary canal at the point of union of the stomach and the large intestine. They gather from the blood and empty into the intestine certain waste products, thus functioning something like the kidneys of higher animals.

The muscular system comprises many sets of muscles, the largest and strongest of which are in the thorax. As there is no internal skeleton the muscles are attached to the hardened portions of the body-wall.

The respiratory system consists of series of small many-branching tubes called *tracheæ*. Their walls are thin and elastic. The external openings of these, the spiracles, have already been noted. From the spiracles short tubes lead to two lateral trunks which send off branches to a pair of dorsal trunks. These lateral and dorsal trunks send branches to all the organs and tissues of the body. The air enters the tracheæ through the spiracles and is carried to all parts of the body, where oxygen is given up to the tissues which need it, and the waste carbon dioxide is carried away.

The reproductive system of the female is easily distinguished if the female has been collected in the fall or late summer before she has laid her eggs. At such a time almost the whole abdomen will be filled by the pair of thin-walled *ovaries* in which may be seen the masses of oblong, brownish or yellowish eggs. Running from the posterior end of each ovary is a small tube, the *oviduct*. These unite near the posterior end of the body and form a single tube which opens between the bases of the valves of the ovipositor. The reproductive organs of the male are similar to those of the female but much smaller. They consist of a pair of *testes* which lie on the dorsal side of the posterior part of the stomach. Leading from the testes are two very small tubes, the *vasa deferentia*, which unite to form a short tube that opens on the dorsal surface of the last segment of the abdomen. These organs cannot be easily distinguished unless the specimen is in just the right condition.

The nervous system is made up principally of a series of

ganglia, small masses of nerve cells and tissue, which are connected with each other by a pair of white nerve cords. The largest of these ganglia is situated in the head above the esophagus and is called the brain. Nerve cords which unite this ganglion with one below the esophagus pass on either side of the esophagus. From this ganglion a pair of longitudinal cords, very close together, pass backward along the floor of the body. At intervals along these cords are ganglia from which fine branching nerve fibers run to all parts of the body.

The circulatory system consists of an elongate, thin-walled dorsal vessel called the heart situated just under the dorsal wall of the abdomen. It is not easily distinguished except in fresh specimens. Its structure will be described in a later chapter where the internal anatomy of a caterpillar is discussed. (See Chapter XVI.) There are no arteries or veins. The colorless blood of the insect fills all the space of the body-cavity not occupied by organs and other tissues, and is in an enclosed vessel only while passing through the heart.

CHAPTER IV

A STUDY OF HYDRA

Frogs and grasshoppers and all the other vertebrates and insects are very complex animals, having their bodies made up of many highly specialized organs and tissues, each part adapted to performing some special life process. There are other many-celled animals much simpler in structure than this, animals without specially developed digestive, nervous, muscular or reproductive systems. Yet they are capable of doing all of the essential things that the more complex animals can do. They can take and assimilate food, respond to stimuli, move, and reproduce their kind. Hydra is a good example of such a simple animal, and as it is to be found in most open fresh-water ponds, in water troughs and other places where the water is not too stagnant, it may be taken as a type for study.

Hydræ will often be found attached to a stone, stick or leaf, or to the green, moss-like plants that are often found in standing water. They may be green or brownish in color and as they are only about one-eighth of an inch long or even smaller, they will have to be looked for very carefully. Once seen, however, they may be easily recognized by the cylindrical body attached by the base and with its free end crowned with a circlet of slender tentacles or arms which lash about slowly while the animal is extended. When touched or alarmed the whole body is quickly contracted and the tentacles drawn in, so that the animal now looks like a simple, small, round or oval projection on the leaf or stone. Food is caught by the tentacles and conveyed to the mouth, which lies in the center at the base of the tentacles. Through the mouth the food passes into a space, the digestive cavity, surrounded only by the body-wall. The food is dissolved in this cavity and the waste parts

thrown out through the mouth opening. The digestive cavity extends out into the tentacles.

In a prepared cross-section, the body of Hydra is seen to be a hollow cylinder with walls made up of two well-defined layers of cells with a thin non-cellular layer between them. Some of the cells of the outer layer, or *ectoderm*, have contractile basal processes running parallel to the long axis of the body.

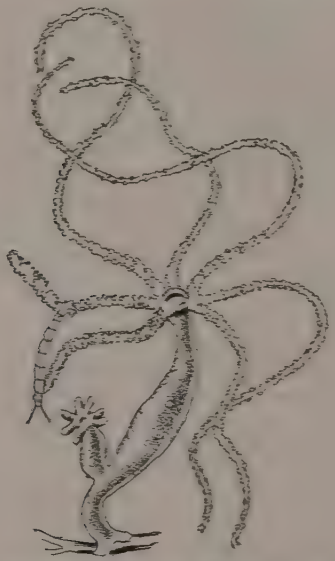


FIG. 6.—Hydra. Note two tentacles catching an insect larva; note the budding young Hydra. Natural size, one-sixth inch; from life.

Like the muscle cells of higher animals these cells contract under certain stimuli, and the whole body of the animal is shortened, as we have seen. Among these cells, particularly on the upper part of the body and on the tentacles, are small *stinging cells* called *nematocysts*. The cells within which nematocysts develop are called *cnidoblasts*, and each is provided at

its outer end with a trigger-like process, the *cnidocil*. The long thread-like tubes that are shot out when the nematocysts are exploded carry a poison called hypnotoxin, which paralyzes or kills minute animals that are stung by them.

The *endoderm* lines the digestive cavity. Some of the endoderm cells are provided with fine threads, or flagella, whose lashings set up currents that waft the food in and out. Other cells are furnished with blunt processes which may surround and engulf some of the food particles. and digest them.

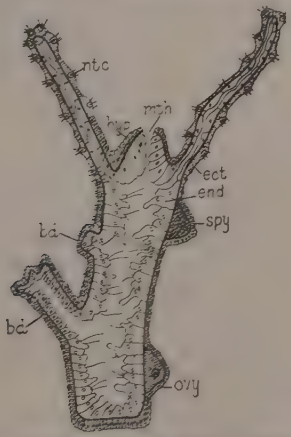


FIG. 7.—Diagram of a longitudinal section of Hydra. *bd*, buds, the upper one just beginning to develop; *ect*, ectoderm; *end*, endoderm; *hyp*, hypostome; *mth*, mouth; *ntc*, nematocysts; *ovy*, ovary; *spy*, spermary. (After Parker and Haswell.)

Some of the endoderm cells have contractile processes like those of the ectoderm. The middle, non-cellular layer is a thin homogeneous layer on each side of which lie the contractile roots of the cells of the ectoderm and endoderm.

Hydra may produce new individuals either asexually or sexually. In some individuals small swellings or buds may be observed. usually near the base. At first these are simply evaginations of the body-wall, but later they develop tentacles

and a mouth of their own. Finally the buds become constricted at the base and separate from the parent. The young Hydræ thus produced soon attach themselves to some object and begin their independent existence. This budding takes place more commonly when food is plentiful and other conditions are favorable. At other times reproductive organs, ovaries and spermaries, may be formed, and the animal produces special germ cells. The ovaries appear as thickenings of the body-wall near the lower end of the body. In each ovary a single ovum or egg develops. The spermaries appear as smaller thickenings of the ectoderm near the tentacles. In them the sperm cells develop. When these reproductive elements are ripe they are cast out into the water where the ova are fertilized by the spermatozoa. Thus Hydra is *hermaphroditic*, that is, both sexes are represented in a single individual. We will find that many worms, snails and some other animals are also hermaphroditic. In such animals various methods are adopted to prevent self-fertilization. In Hydra this is prevented by the ova and spermatozoa in any individual usually ripening and being cast into the water at different times. The fertilized ovum soon divides into a large number of cells, forming the embryo, and after becoming surrounded by a hard shell or cyst drops to the bottom of the pond where it may remain for some time before it goes on with its development.

Sometimes, through accident, a Hydra may be cut into two or more pieces. Each part has the power of developing into a new individual Hydra just like the original. This power of developing anew parts of the body that may have been lost is possessed by many other animals, especially the lower ones, and is known as *regeneration.*

CHAPTER V

A STUDY OF AMŒBA

The animals that we know best are all comparatively large and have a body composed of many cells. Ordinarily we think of a mouse or a humming-bird as being very small, but in the insect world there are hosts of animals so small that they can hardly be detected without the use of a magnifying lens. Yet even the smallest of them are as giants when compared with any of the one-celled animals, the Protozoa (Gr. *prōtos*, first; *zōon*, animal), very few of which can be seen with the unaided eye. Before the invention of the microscope the Protozoa belonged to an unseen and unknown world. The earliest lenses enabled the observers to see some of the largest of them, and each improvement of the microscope has enabled us to penetrate further and further into this fascinating field. Now we know in detail the structure and life history of many of these almost inconceivably minute animals.

Most of the Protozoa live in water, but a few live in damp sand or moss, while many live in the bodies of other animals where they may or may not cause serious injury. No mountain stream is too pure, no ditch too foul to be the home of some of these simple animals.

Amœba.—Among the most familiar of these one-celled animals are the Amœbæ. They are most easily found in pools of water, either in the slime or ooze on the bottom or in the sediment that has settled on submerged leaves or sticks. If some of this material is collected and poured into a dish of water and allowed to settle for a few hours, Amœbæ may usually be found when small drops of the slime are examined on a slide under the microscope. With the low-power lenses they appear as small, semi-transparent, irregular-shaped objects which, if watched carefully, will be seen to move very slowly.

Using the higher power lenses it will be seen that the outer part of the jelly-like body, called *ectosarc*, is clearer than the more granular inner part, the *endosarc*, and that within the endosarc are many small granules, the food particles, and a comparatively large, round, clear space, the *contractile vacuole*, which

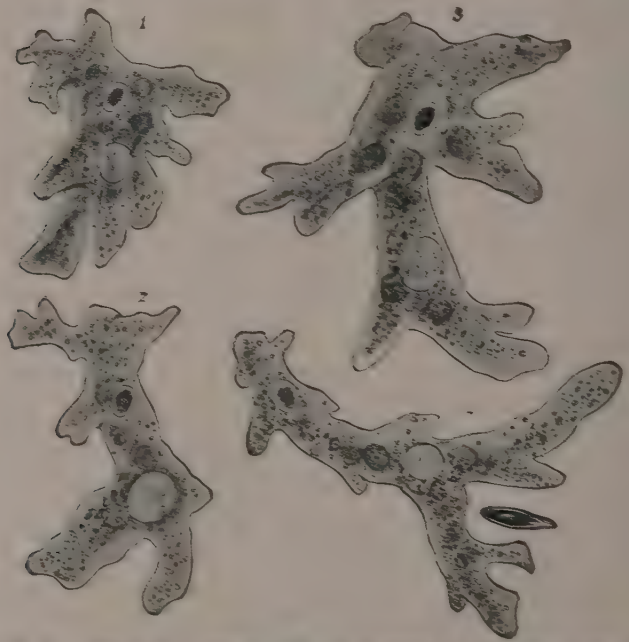


FIG. 8.—*Amœba* sp. Showing the forms assumed by single individual in four successive changes. (Greatly magnified; from life.)

appears and disappears with more or less regularity. Sometimes the darker, denser *nucleus* can be seen in the living Amœbæ, but it shows much more distinctly in specimens killed by allowing a little carmine or other staining fluid to run under the cover-glass.

Active Amœbæ are constantly changing their shape, and by

these changes they effect a slow, flowing movement. Small unequal projections, called *pseudopodia*, stretch out from various parts of the body. At first these are formed only by the ectosarc, but as they grow longer and larger the endosarc flows out into some while others are withdrawn and new ones are thrown out. The outline of the body thus continually changes. As the animals move slowly about they come in contact with other minute animals or plants around which the pseudopodia flow and these organisms, which the Amœba uses for food, are thus taken directly into the body. Any particles of food or other substances which are taken into the body and not digested pass out just as they entered, that is, the Amœba flows away and leaves them, much as a drop of oil that surrounded a particle of sand might flow away and leave the sand.

The oxygen that the Amœbæ need is absorbed from the surrounding water. Some of the waste excretions of the body are absorbed directly by the water, others are forced out by the contractile vacuole.

Thus we see that while the Amœba has no mouth or alimentary canal, no lungs or heart, muscles, glands or any of the special organs and tissues that go to make up the higher animals, this minute speck of living substance moves, feeds, respires, excretes and does all the essential things that the more complex organisms do. As the Amœba feeds it grows until it reaches a more or less definite size, then certain changes take place in the nucleus which soon divides into two equal portions, one portion withdrawing to one part of the body and the other part to the opposite end. Then the substance around the nuclei begins to divide, a portion collecting around each of these nuclei. Finally the two halves pull entirely away from each other and thus two new Amœbæ are formed, each like the original, but only half as large.

Amœbæ continue to live and multiply as long as the conditions surrounding them are favorable. But when the pond dries up the Amœbæ in it would be exterminated were it not for a careful provision of nature. When the pond begins to dry up each Amœba contracts its pseudopodia and secretes

a horny capsule about itself. It is now protected from dry weather and can be blown by the winds from place to place. If it again reaches water it expands, throws off the capsule and commences active life again in the new pond.

CHAPTER VI

ONE-CELLED ANIMALS (BRANCH PROTOZOA)

The Amœba which has just been studied is one of the simplest of the one-celled animals. Others while still retaining the one-celled condition, become more highly specialized along certain lines and show a wonderful power to adapt themselves both in form and habits to the various conditions under which they live. A brief study of a few of these will be worth while.

Paramœcium.—Paramœcia are usually found in considerable numbers in any pond of stagnant water. A good supply can often be obtained by placing sticks or leaves from a pond, together with some dry hay or clover, in a dish, which is then filled with water and allowed to stand for several days. When very abundant the Paramœcia may even be seen with the unaided eye as minute white specks near the edge of the dish. Examined with the low power of the microscope they will be seen as very active, slipper-shaped animals much larger than the Amœbæ. As they move about so rapidly it is desirable to put them into some thicker medium, such as a thin mixture of cherry gum; or a few shreds of cotton may be put under the cover-glass and some of the Paramœcia will become entangled in this in such a way that they may be studied.

It will at once be seen that Paramœcium differs from Amœba in many respects. It has a definite and persistent elongate-oval shape, roughly like that of a slipper, hence it is often called the slipper animalcule. There are definite anterior and posterior ends and dorsal and ventral sides, and the body is covered with minute *cilia*, fine hair-like projections, which vibrate very rapidly and propel the animal through the water. On one side, beginning at the anterior end and extending more than half the length of the animal, is a *buccal groove*, which is provided with many small cilia which drive water currents and

all kinds of particles into the *gullet* which opens into the interior. Food particles surrounded by a film of water are taken into the body through this opening and are digested just as they are in the body of the Amœbæ. The water drops are ejected at a spot in the cell membrane just below the gullet. If a little finely powdered carmine is added to the water in which the Paramœcia are swimming some of the grains will be taken into the body where they will be seen to follow a rather definite course from one end of it to the other. Instead of one contractile vacuole as in the Amœbæ there are two, and there are also two nuclei, which can be seen in specimens stained with carmine. The large one, ovoid in shape, is called the *macronucleus*, and the smaller oval one close beside it is the *micronucleus*.

FIG. 9.—*Paramœcium* sp. Buccal groove at right. (Greatly magnified; from life.)

Between the bases of the cilia there may be seen many minute oval sacs lying side by side. These are called the *trichocysts*, and from each a fine stinging thread can be thrust out which, it is believed, help to protect the Paramœcium from other minute animals.

The Paramœcia reproduce by simple division as do the Amœbæ. The macro- and micro-nuclei divide and the body becomes constricted in the middle and the organism is finally divided into two smaller animals which soon grow to be like the original. But after multiplication has gone on in this way for many generations, often from one to two hundred or more, the Paramœcia seem to be unable to divide further until a new process takes place. Two Paramœcia approach each other and unite, usually with their buccal grooves together; then there

is a breaking up of the nuclei and a part of the micronucleus of each individual passes over to the other. Then the Paramœcia separate and each divides into two. This is, in very simple condition, the process of fertilization, which occurs in more elaborate condition in all the higher animals.

Vorticella.—Many other minute organisms will be found in the drops of water that have been examined while looking for the Amœbæ and Paramœcia, but of these we wish to call particular attention to but one. On the leaves or sticks that have been collected from ponds and placed in vessels of water, tiny whitish mould-like tufts may sometimes be seen. Touch such a spot with a needle and it may contract instantly. If so, it is probably a colony of Vorticella, or bell animalcules. Such a mass, examined under the lens, will be seen to be made up of a number of attached slender stalks each having a bell-shaped free end, hence the common name, bell animalcule. When the stalk is extended it is straight or somewhat curved but when the animal is disturbed the stalk contracts into a close spiral. The thickened upper outer margin of the bell, the *peristome*, and the central disk, the *epistome*, are fringed with rather long cilia. Between the peristome and the epistome is a groove, the mouth or *vestibule*, which leads into the body. The substance comprising the body is differentiated into an outer uniformly granular ectosarc and a more transparent, colorless endosarc, in which are numerous large food vacuoles, a large clear contracting vesicle, a large curved macro-nucleus, and near it a micro-

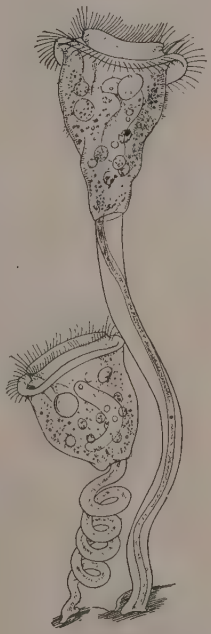


FIG. 10.—*Vorticella* sp. One individual with stalk coiled, and one with stalk extended. (Greatly magnified; from life.)

nucleus, the latter often being difficult to see unless the specimens are stained. The slender stalk is made up of a clear outer portion and a denser contractile inner rod.

The Vorticellæ multiply by longitudinal division, or fission. In this process a cleft first appears at the distal end of the bell-shaped body and gradually deepens until the original body is divided quite in two. The stalk also divides for a very short distance. One of the new bell-shaped bodies develops a circlet of cilia near the stalked end. After a while it breaks away and swims about by means of this basal circlet of cilia. Later it settles down, becomes attached by its basal end, loses its basal cilia and develops a stalk. Conjugation sometimes occurs between two individuals. Under certain conditions there is produced, by repeated divisions, small free-swimming forms, one of which may meet one of the large stalked forms and be completely absorbed by it. This differs from the process of fertilization in the Paramœcia in which the union was only temporary, and presents an even more striking analogy with the process of sexual reproduction occurring in the higher animals.

Marine Protozoa.—The Protozoa are more abundant in the ocean than they are in fresh water. Although the ocean water may appear to the unaided eyes as clear and free from living things, yet a microscopical examination will show it to be swarming with minute animals and plants. These are found at all depths, from the surface to the deepest parts of the ocean, and are interesting not only because they represent the lowest, simplest and doubtless earliest kinds of animals that appeared on the earth, but because they furnish, together with the *Protophyta*, or one-celled plants, directly or indirectly, food for all of the other animals of the sea. As we study some of the representatives of the higher groups of ocean animals we shall see that many of them are particularly adapted by structure and habit for feeding on these minute organisms, and that they in turn serve as food for other animals, so that finally all of the animal life in the ocean becomes dependent on the one-celled organisms for their food. This is one of the reasons for believing that the Protozoa were the first

animals to appear in the ocean, and as ocean life is older than terrestrial life it is probable that certain marine Protozoa are the most ancient of all animals.

Some of these marine Protozoa, as the *Foraminifera* and the *Radiolaria*, secrete a tiny shell of lime or silica which encloses most of the body. When these animals die their shells sink to the bottom where, as they slowly accumulate, they form a thick layer over the floor of large areas of the ocean. The

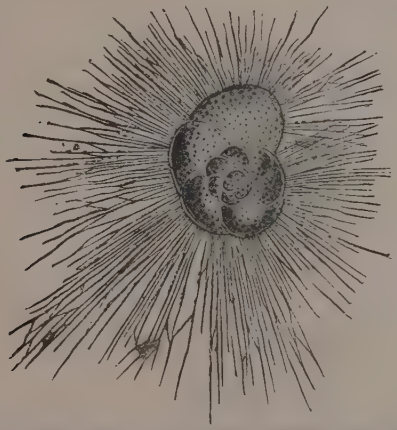


FIG. 11.—A marine Protozoan, *Rosalina varians* (Foraminifera), with calcareous shell. (Greatly magnified; after Schultze.)

ooze thus formed is called Foraminifera ooze or Radiolaria ooze, according to which order of Protozoa chiefly formed it. All over the world are found great strata of rocks that are formed almost exclusively of the fossil shells of these Protozoa. The extensive chalk beds and cliffs of England, France, Greece, Spain and America were made by Foraminifera, whose shells were deposited there when these places were parts of the ocean beds. The siliceous rock called Tripoli, found in Sicily, and the Barbadoes earth from the island of Barbadoes are composed of the shells of ancient Radiolaria.

Parasitic Protozoa.—Because of their simple structure and physiology the Protozoa easily adapt themselves to new modes of life, when conditions are favorable. It was an easy step from an existence in the water to life in the blood tissues of some of the aquatic animals or in some of the higher animals, and the Protozoa that have made this step have come to be among the greatest scourges that affect mankind. These parasitic Protozoa are so important that a later separate chapter will be devoted to an account of them. (See Chapter XXVIII.)

Classification of the Protozoa.—The branch Protozoa is divided into five groups or classes, the divisions being based principally on the manner in which the members of the different groups move about. The *Amœbæ*, the *Foraminifera* and the *Radiolaria* belong to the class *Rhizopoda* (Gr. *rhiza*, root; *pous*, foot). Rhizopoda means "root-footed" and the name is applied to those Protozoa which move about by means of the extending or flowing out of the root-like processes called pseudopodia, or false feet.

Paramœcium and *Vorticella* belong to the class *Infusoria* (L. *infusus*, infused), a name that was early used because these organisms are so frequently found in infusions. Because their body is furnished with minute hair-like organs called cilia they are often called *Ciliata*.

From an economic point of view the class *Sporozoa* (Gr. *spora*, seed; *zōon*, animal) is the most important. The members of this class are parasitic and cause some of the most serious diseases of man and other animals, such as the various malarial fevers, the spotted fever of man, and the Texas fever of cattle.

The whip-bearers (class *Mastigophora*, Gr. *mastix*, whip; *phero*, bear) also include a number of important parasites, as the *trypanosomes* that are the cause of the dreadful disease which ends in sleeping sickness, and the *Spirochætæ*, which are the cause of certain relapsing fevers. The little green *Euglena*, whose presence in standing pools often imparts a greenish color to the water, and the wonderfully phosphorescent *Noctiluca* of ocean waters, also belong to this class. The

Noctilucæ live near the surface, and when disturbed at night their little bodies glow like coals of fire. This class also includes a number of so-called colonial Protozoa such as *Volvox*, *Proterospongia* and others. These are more or less closely associated groups of similar individuals or colonies in which the individual members show some differences and have more or less special functions to perform.

The members of the class *Mycetozoa* (Gr. *mykes*, fingers; *zōon*, animal) resemble fungi in many respects and are often included with them under the name "slime moulds." They are of no economic importance.

Protoplasm and the Cell.—All the Protozoa have the body composed, for its whole life, of but a single cell. By cell is meant not necessarily a little enclosed or box-like bit of animal substance, but simply a small (usually microscopic) mass of *protoplasm* which is composed of an inner, denser part called *nucleus* and a surrounding less dense part called *cytoplasm*. Protoplasm itself, "the physical basis of life," is a substance or group of substances, usually viscous or jelly-like, which always contains certain very complex albuminous chemical compounds called *proteins*. These proteins are never found in inorganic matter and are always fround in living tissues. Proteins contain carbon, oxygen, hydrogen and nitrogen, and are almost the only group of substances found in living matter of which chemists have not yet been able to make representatives in the laboratory. Besides the all-important proteins protoplasm usually includes certain other characteristic compounds known as carbohydrates and fats (which contain no nitrogen), and various salts and gases, and always water. The gases are oxygen and carbon dioxide, and the salts are compounds of chlorine as well as the carbonates, sulphates and phosphates of the alkalies and alkali earths. Common salt (sodium chloride) is almost always present.

What a Single Cell Can Do.—All the larger animals are composed of many cells which are grouped together to form organs or tissues each with its special function to perform, but the minute one-celled mass or protoplasm forming the whole body of each Protozoan is able to carry on all the necessary

processes of life, digestion, assimilation, respiration, excretion, secretion, and to reproduce others of its kind. It is this wonderful capacity for living that separates the one-celled organisms, simple as they may seem to be in comparison with higher plants and animals, by a wide gulf from the most complex of inorganic bodies. Some scientists have been able to produce in their laboratories particles of matter that closely resemble, in many respects, these simple organisms, but none has yet been able to endow these creations with the subtle power which we call life.

We have found, moreover, in our study of the Protozoa that while they are each composed of but a single cell, or, rarely, of a group of cells temporarily united to form a colony, the cell itself may be very complex in its structure, some parts of it adapted for protection, other parts for locomotion or food getting. There may be a definite upper and lower side and anterior and posterior end, and there may be many other specializations of parts that especially fits each of these one-celled animals to live in its particular place.

Spontaneous Generation.—People used to believe that many animals were spontaneously generated. When myriads of fly larvæ mysteriously appeared in a mass of decaying matter it was supposed that they had been generated there spontaneously. When great numbers of frogs or insects or any other animals appeared from some unknown source the phenomenon was explained by spontaneous generation. Long after it had definitely been shown that none of the larger animals could arise in this way, many still held to the belief that at least the simplest animals and plants arose in this way. If a vessel of ordinary water in which there are apparently no living organisms be allowed to stand for a few days it will usually be found to be swarming with minute animals and plants. The source of this life was a mystery to the older observers, but we know now that some of these organisms come from others that were already in the water and some come from spores that are constantly in the air. If a bottle of water is boiled thoroughly enough to kill all the organisms in it, and then closed so tightly that no germs or spores can reach it from the outside, it will

remain perfectly sterile, that is, no living animal nor plant will ever appear in it.

Reproduction in Protozoa.—All life comes from life. Every living creature is the offspring of some other living creature. This is just as true for the Protozoa as for the higher animals, but their method of reproduction is usually much more simple. In many cases the Protozoan animal simply divides into two more or less similar smaller animals which grow until they attain a certain size and then divide again, and the process is continued for generation after generation. This is called reproduction by simple division or fission.

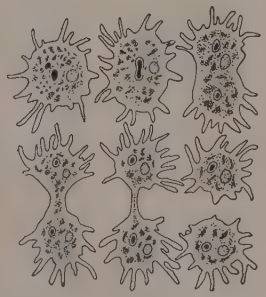


FIG. 12.—Division of Amœba. (Greatly magnified; after Schultze.)

Protozoa that thus live and reproduce by simple division have been called immortal, and it would seem that under natural conditions such animals never die, for as soon as they reach a certain size they divide and form two new individuals and as this process is continued for generation after generation there would seem to be no death of the individual. Careful studies have shown, however, that this process of simple division cannot continue indefinitely unless there is introduced into the cycle from time to time the extraordinary process known as fertilization by which the mature or old individuals are rejuvenated. In many of the Protozoa this process of fertilization is accomplished by the conjugation of two similar individuals in which two animals come together and undergo complete or temporary fusion. Such a conjugation is followed by renewed activity, the process of division going on more rapidly than before.

Many Protozoa instead of dividing directly into two parts go through a process called spore formation. The animal becomes encysted in a firm little sac or cyst in which it remains for some time. Then it divides into many small bodies, called

spores, which finally burst out into the water or other medium in which the animal lives, where each spore develops into an organism like the parent. This process makes it possible for the animals to multiply very rapidly, and we shall see something of its importance when we come to study the Sporozoa, a group of parasitic Protozoa which all reproduce in this way and some of which are the causes of certain common diseases of man and other animals.

CHAPTER VII

ONE-CELLED AND MANY-CELLED ANIMALS

Of the animals so far studied, Amœba, Paramœcium, Vorticella and their allies have the minute body composed of but a single cell. The others, the frog, grasshopper and hydra, have the body composed of many cells. This distinction of one-celled and many-celled body has led to the classification of all animals into two primary groups, the Protozoa, including all those with one-celled body, and the Metazoa, all those with a many-celled body. They are groups of very unequal size, as of the 500,000 (approximated) known kinds of living animals all but about 10,000 are Metazoa. But the distinction between Protozoa and Metazoa is very important; it is indeed one of the most fundamental in animal structure and classification. For although many-celled animals are undoubtedly derived by descent from one-celled ones, yet the group of single-celled animals, the Protozoa, is much larger than we should expect it to be if it were simply the beginning of the animal scale. It is not only a beginning stage in animal evolution, but it is an evolutionary line of its own. There is a great deal of variety and complexity in the structure, physiology and mode of development within the protozoan branch. All this diversity has, however, to be limited to the differences possible to a single cell. The moment animal evolution made the step from independent single cell to mutually dependent many cells, united for life, infinitely greater possibilities of diversity in structure and function and life history were open. And the extraordinary variety of animal life as it appears to us now in the various groups of Metazoa, is the result of Nature's taking advantage of these possibilities.

But the step was not a sharp one, nor was the attainment of present-day animal complexity and diversity brought about

at all speedily. It was millions of years after the first many-celled animals appeared on the earth before the first insect appeared. And still millions of years later before the first backboned animal was evolved.

As to the step from isolated single cell to united many cells, it was undoubtedly made in the simple way still represented by a few living organisms known as Volvocinæ, sometimes called plants, and sometimes animals. These are one-celled organisms that live as small colonies or groups of cells. These few cells, only sixteen in the case of several of these organisms, are all derived from a single cell by its division into two and the succeeding divisions of these two into four, the four into eight and the eight into sixteen. And they are all alike. They remain together in the form of a tiny ball, the cells all imbedded in a soft gelatinous substance secreted by them. Each cell has a pair of flagella, and the waving of all the flagella moves the little ball through the water. Each cell can take up food, respond to stimuli, and in fact do all the things that we have found are essential to living and which are done in the simplest manner by the one-celled animals. Indeed it is probable that each cell could live independently; and as a matter of fact each one does for a short time when the colony breaks up after reaching maturity.

For when this little colony is mature and ready to reproduce itself, the gelatinous stuff dissolves, the sixteen cells are set free in the water, and each, by repeated division may produce a new colony. Or a process of conjugation between pairs of the freed cells can take place, and from each paired cell formed by the conjugation of the two, a new colony may be formed by simple division.

Differentiation and Specialization of Cells.—If this first step toward making a many-celled animal out of a single-celled one seems simple, the next step does not. In the simplest kinds of true many-celled animals an important new condition appears. It is a condition of differentiation or specialization of the cells united to form the body. The cells are no longer all alike in appearance, and no longer have identical capacities. Only a few of them remain in simple generalized condition. These

are the so-called white blood corpuscles which have an appearance much like that of the Amœbæ and have a great deal of freedom or independence in their life.

The rest of the hundreds or thousands or millions of cells that go to make up a many-celled animal's body differ greatly in appearance and behavior from Amœbæ, and differ also greatly among themselves. Besides the amœboid white cells in the blood there are, in red-blooded animals, many elliptical, disk-like reddish cells and they have an entirely different function from that of the white cells. The cells composing the muscles are, moreover, not like either of the kinds of blood cells; the cells of which the liver is composed are not like the cells of the muscles; and the cells which compose the organs of the nervous system, brain, ganglia and nerves, differ markedly from those of the blood, muscles and liver, and differ also very much among themselves.

Each of these kinds of cells, and each of the many other kinds that exist in the body of one of the higher animals, has become specialized in order to devote itself to a certain particular function or special work. For example, the cells of the nervous system devote themselves to the function of receiving and transmitting sensation. The muscle cells have developed to a high degree the power of contractility, and they have for their special function this one of contraction. Massed together in great numbers, they form the strongly contractile muscles of the body on which the animal's power of motion depends. The cells which line certain parts of the alimentary canal are the ones on which the function of digestion largely rests. And so we might continue our survey of the whole complex animal body. The point of it all is, however, that the thousands of cells which compose many-celled animal bodies are differentiated and specialized. That is, have become changed or modified from the generalized primitive amœboid cell condition so that each kind of cell is devoted to some special work or function, and has a special structural character fitting it for its special function.

Organs and Functions.—The specialized cells are grouped into tissues and organs. These organs are known to us

familiarly as various parts of the body, such as lungs, heart, muscles, eyes, stomach, etc. The life of an animal consists of the performance by it of various processes, such as breathing, getting and digesting food, circulating blood, moving, seeing, etc. These various processes or functions are performed by the various parts or organs of the body.

The whole body of a many-celled animal is thus really a machine composed of various parts, each part with its special work to do but all depending upon one another and operating to accomplish the work of living. The locomotive engine is a machine similarly composed of various parts, each part with its special work or function, and all the parts depending on one another and so working together as to perform satisfactorily the work for which the locomotive engine is intended. An important difference between the locomotive engine and the animal body is that one is a lifeless machine and the other a living machine. But there is a real similarity between the two in that both are composed of special parts, each part performing a special kind of work or function, and all the parts and functions so fitted together as to form a complex machine which successfully accomplishes the work for which it is intended. And this similarity is one which should help make plain the fundamental fact of animal structure and physiology, namely, the division of the body into numerous parts or organs, and the division of the total work of living into various processes which are the special work or functions of the various organs.

Essential and Accessory Life Processes.—A very complex animal, such as a dog, performs a great many different functions, that is, does a great many different things in its living. But there are many animals in which the body is composed of but a few parts and whose life includes the performance of fewer functions or processes than in the case of a dog. There are many animals that have no eyes, nor ears, nor organs of special sense. There are animals without legs or other special organs of locomotion; some animals have no blood and hence no heart nor arteries and veins. But in the life of every animal there are certain processes which must be performed, and the

body must be so arranged or composed as to be capable of performing these necessary life processes. All animals take food, digest it and assimilate it, that is, convert it into new body substance; all animals take in oxygen and give off carbon dioxide; all animals have the power of movement or motion (not necessarily locomotion); all animals have the power of sensation, that is, can feel; all animals can reproduce themselves, that is, produce young. These are the necessary life processes. It is evident that the dog could still live if it had no eyes. Seeing is not one of the necessary functions or processes of life. Nor is hearing, nor is leaping, nor are many of the other things which the dog can do; and animals can exist, and do exist, without any organs to enable them to see and hear and leap. But the body of an animal must be capable of performing the few essential processes which are necessary to animal life. How surprisingly simple such a body can be our study of the Protozoa has already shown. But in most animals the body is a complicated object, and is able to do many things which are accessory to the really essential life processes, and which make its life complex and elaborate.

The Principal Systems of Organs and Functions.—These complex life processes are usually carried on by systems of organs which are known as the skeletal, muscular, digestive, respiratory, circulatory, excretory, nervous and reproductive systems. And the particular set of special functions or life processes connected with each is sufficiently indicated by its name. Of them all, the reproductive system and its function, which is that of the multiplication of the species, calls for a few special words of introduction before we pass to the consideration of the successive animal groups. For it is in connection with this function that some of the most important special conditions in animal life exist. The important fact of sex, for example, is correlated with this function, while the whole subject of animal development may be looked on as part of the study of animal multiplication.

Reproduction and Development in the Metazoa.—We have learned that the process of multiplication among the Protozoa is, in most cases, very simple, consisting of the simple splitting

of the parent's body in two. Previous to this splitting in two there may be a temporary fusion for the purpose of a mutual exchange of part of the body substance, or a permanent conjugation of two individuals. The process of reproduction among the many-celled animals is far more complex, and certain particular organs of the body of complex structure are specially devoted to this function. The results of the process, however, are the same as among the lower animals, namely, the production of new individuals. The manner in which the reproductive process is carried on, and the number of new individuals produced by a single parent individual, may and do vary much among different animals.

Among some of the simpler many-celled animals the new individual is sometimes produced by the growth of an external bud, or by the splitting off of a small part of the parent's body, a process much like the fission, or splitting in two, of the one-celled animals. But this is an unusual method, and possible to comparatively few animals. In almost all cases the young come from eggs, or ova, which are produced inside the body of the mother. These eggs usually issue from the body before hatching, but in some animals, as all the Mammalia, the young develop from the ova inside the body and are born as active free animals, resembling the parent more or less in appearance and structural character, although of course much smaller.

In all cases the young animal has to undergo a certain amount of development and growth, which extends over a longer or shorter period of time, before it is really like its parent, that is, before it is a fully developed, full-grown individual. No animal is born fully developed; it is born from the body of its mother or hatched from its egg in an immature condition, and growth and change are necessary before we have a fully developed rabbit or robin, or any other kind of animal.

But when we begin the study of the life history of the new animal with the time of its emergence from the body of the mother or from the egg, we are not beginning at the beginning. When we first see the new animal it is already of appreciable size and complex structure. But at its very beginning inside the body of the mother it is, in every case, simply a single cell.

Every individual begins as a single cell, and develops and grows from this single cell to its final complex adult condition. The first single cell is called the fertilized egg cell or ovum, and an egg is simply this primary germ cell, or the embryo which develops from it, together with a greater or less amount of yolk (which is food for the germ), enclosed in a membrane or shell. In the case of those animals which do not lay eggs, but give birth to their young in a free condition, the egg, which is kept inside the body of the mother, is usually composed of the germ alone, food being provided the embryo directly from the body of the mother. After the young has reached a certain stage in its development, it leaves the body of the mother and food is provided it by suckling or in some other way. The development of an animal from first germ cell to the time it leaves the body of the mother, if born free, or until it is hatched from an egg, is called its *embryonic development;* and the development from then on is called the *post-embryonic development.* Beginning students of zoology cannot study the embryonic development (*embryology*) of animals readily, but they can in many cases follow the course of the post-embryonic development, and this study will always be interesting and valuable

It is a kind of study of particular importance to the economic zoologist, because in all attempts to make better uses of animals, or to restrain their injuries, a knowledge of their *life history* is essential. This life history includes the facts of their development and the facts of their habits and general behavior both in immature and mature condition. In the case of an injurious insect, for example, the times and place of egg-laying, the character and duration of the immature stages, the time and place of pupation, etc., are all important conditions. A knowledge of these may enable the economic zoologist to hit upon exactly the best means for combating the pest.

The radical changes or metamorphoses undergone during development by many insects must be taken into account in any consideration of them as possible enemies of man. Young grasshoppers, for example, are wingless and can be captured and killed by simple methods which would be of no use in the

case of the mature flying individuals. Indeed even simpler and more effective means can be brought to bear against the eggs of the grasshoppers. But a knowledge of the times, places and peculiar manner of the egg-laying of grasshoppers was necessary as a basis for devising these remedies. Butterflies and moths take only plant nectar and water for food, and are harmless—in the adult stage. But in their immature stage, as strong-jawed biting larvæ (caterpillars) many kinds are extremely injurious. The mosquito is annoying as a blood-sucking pest and dangerous as a breeder and disseminator of yellow and malarial fevers only as a full-developed flying adult, but it is only in its immature or larval and pupal stages passed in quiet water that it can be successfully fought. The student of economic zoology then should give a special attention to the study of animal multiplication and development.

Sex and the Fertilization of the Egg.—Among the one-celled animals we found that before an individual divided into two, that is, multiplied, it sometimes met another individual with which it exchanged body substance. Among most of the many-celled animals the germ cell or fertilized egg cell which develops into a new individual is produced by the fusion of two so-called reproductive cells from two distinct individuals of the same species or kind of animal.

The reproductive cells produced by the females are known as eggs or ova, and are usually produced in the ovaries; those produced by the male are called spermatozoa and are produced in the spermaries, or testes. Before the ova can begin their development they must be fertilized by the spermatozoa. There are a few exceptions to this general rule, young being produced by some kinds of animals from unfertilized eggs. But these cases are comparatively rare and in most of them fertilization of some of the eggs, at least, takes place also.

We shall find among the Metazoa various devices to aid in bringing the ova and spermatozoa of two individuals of a kind together. Many of the aquatic animals simply cast their reproductive cells into the water where they meet by chance. Of course many of the ova thus thrown out are never reached by the spermatozoa and so no development takes place, but

when the eggs are laid in this way they are always produced in great numbers. An average sized oyster will produce during the season about 16,000,000 eggs and a large old female may produce more than three times that many during the few summer months that she is breeding. The number of spermatozoa that are produced by a male oyster is simply inconceivable, and the water in the vicinity of the oyster beds is literally swarming with these minute cells during the breeding season. These enormous numbers are made necessary by the fortuitous mode of fertilization. It is a condition comparable with that of the great production of pollen and chance method of pollination in the case of the pines and other wind-pollinated flowers.

Other aquatic animals, as certain fishes, lay their eggs in a more or less carefully prepared nest, and the male soon passes by and deposits the milt, which contains the spermatozoa, over them. With most of the higher animals, however, the ova are fertilized while still inside the body of the mother, and various provisions are made for transferring the spermatozoa from the male to the female.

CHAPTER VIII

THE CLASSIFICATION OF ANIMALS

The first thing one asks about an animal new to one's experience is, what is its name? It is really less the name itself that we wish to know, than the information that this name gives regarding the placing of the animal in some classificatory relation with other animals. It is the classifying interest that impels our question; and with most of us it is this interest —which in turn usually develops from a collecting interest— that first attracts us to the study of zoology.

Meaning and Basis of Classification.—However, if classifying animals meant only arranging them in simple groups of similar or dissimilar forms, and naming them, the classificatory interest would deserve the reproaches so often heaped on it by naturalists more interested in anatomy or physiology or development. But classifying animals means much more than that. Since the days of Darwin's "Origin of Species," when the theory of the evolution of animals and plants was so clearly explained and proved that the world could not help but accept it as true, the classification of living things has had a new and great importance. It has the importance of representing our knowledge of organic evolution, for the classifying of animals and plants now means arranging them in groups according to their descent.

In the early days of the study of animals and plants their classification or division into groups was based on the external resemblances and differences which the early naturalists found among the organisms they knew. But later when naturalists began to dissect animals and get acquainted with the whole body, the differences and likenesses of the inner parts, such as the skeleton and organs of circulation and respiration, were taken into account. For we know that animals which are

really closely related may not, on the surface, closely resemble each other. The outside of their bodies may become much modified to adapt them to different environments. But their internal structure and their development will usually reveal their nearness or relation. On the other hand, animals not closely related by descent may become and look superficially like each other by becoming adapted to living in the same environment, taking the same kind of food, etc. But again a study of the development and internal anatomy will usually establish marked differences, indicating their lack of real genealogic nearness.

Modern zoological classification, is, therefore, based on a great deal of serious study of animal structure and development and represents, as we have already said, our present knowledge of the actual blood relationships of animals. It means more than that animals of the same group resemble each other in certain structural characters. It means that the members of a group are related to each other by descent, that is genealogically. They are all the descendants of a common ancestor; they are all sprung from a common stock. And this added meaning of classification explains the older meaning; it explains why the animals are alike. The members of a group resemble each other in structure because they are actually blood relations.

The history of animal classification with all the changes in it, and the succeeding points of view and new significance represented by these changes, is an interesting chapter in the history of science. It began, in any real way, with Linnæus, the great Swedish naturalist who worked in the middle of the eighteenth century. In the years just before and after 1750 he published successive editions of his "Systema Naturæ," which was the first attempt to describe and name and classify all the known kinds of animals and plants. In the 10th edition (1758) of this "Systema" he catalogued about 4000 kinds of animals. (Now we know 500,000 kinds!)

In this great catalogue he adopted a system of short scientific names, one for each kind of organism. And he classified all these named animals into groups of successive degrees of

inclusiveness, which he called, *species*, *genus*, *ordo* and *classis*. We still use Linnæus's general system of classification and most of his short two-word scientific names for the different animals and plants that he knew, but we base the classification on other grounds than the superficial resemblances that he used, and we see in our classification a more far-reaching significance and a much greater importance than he saw. But Linnæus was the first great animal classifier, or systematic zoologist, and deserves all honor for his important work.

Animal Names.—Well-known animals have common, or vernacular names, but less familiar ones do not. Also these common names differ in different countries; that is, are different in different languages. The animal we call dog, the Germans call *Hund*, the French, *chien*, and the Italians, *cane*. And even in the same country one common name may be applied in different parts of it; as "quail" which means one kind of bird in the East, another kind in the Mississippi Valley, and still another on the Pacific Coast. "Partridge" has still a wider divergence of application, and "minnow" refers to nearly as many different fishes as the localities in which the word is used.

Thus if there is to be accurate speaking and writing about animals, and if the naturalists of different countries are to be able to use names that are understandable to all, there is necessary some system of naming animals other than the popular one of vernacular names. This system is that of the so-called "scientific names," or two-word names in Latin or Greek, devised and successfully established by Linnæus. It is a system which has given rise to much popular fun-making and no little scientific discussion and dispute, but whose usefulness is so real and whose principles are so sound that it will likely never be given up.

The names used in it are all Latin or Greek simply because these classic languages are taught in the schools and colleges of almost all the countries of the world, and are thus intelligible and familiar to naturalists of all nationalities. In the older days, indeed, all the scientific books, the descriptions and accounts of animals and plants, were written in Latin, and now

most of the technical words used in naming the parts of animals and plants are Latin. So that Latin may be called the language of science. For most of the groups of animals we have English names as well as Greek or Latin ones and when talking with an English-speaking person we can use these names. But when scientific men write of animals they use the names which have been agreed on by naturalists of all nationalities and which are understood by all of these naturalists. These Latin and Greek names of animals, laughed at by non-scientific persons as "jaw-breakers," are really a great convenience, and save much circumlocution and misunderstanding.

Zoological Classification and Nomenclature.—In any discussion of the nomenclature of zoological classification it is first of all necessary to distinguish between the few names used as common nouns, such as species, genus, family, order, etc., which denote the different kinds of groups into which animals are divided, and the host of proper noun names which are applied to the many groups of each kind which have been established by students of systematic zoology.

A single kind of animal, as a house-fly, a robin or a coyote, is called a *species* of animal. Coyotes, dogs and gray wolves are different species much alike. They are grouped together with some other kinds of wolves and dog-like animals to form a group called a *genus*. The robin belongs to a genus which includes one or two other robin-like species of birds and the house-fly to a genus which includes several other house-fly species of insects. Each of these genera has a proper name, which distinguishes it from all other genera, and for that matter from all other groups of animals, because a genus name is never used for more than one group of animals. The dog-coyote-wolf genus is called *Canis*, the robin genus, *Merula*, and the house-fly genus, *Musca*.

Each species belonging to these genera also has a specific proper name, the dog's species name being *familiaris*, the coyote's *latrans*, the gray wolf's *occidentalis*, the robin's *migratoria*, and the house-fly's *domestica*. But because of the enormous number of kinds of animals we do not try to have a separate single word name for each species, but always com-

bine the species name word, which may be used repeatedly, that is, used for several different species, with the name of the genus to which the species belongs, and thus make a two-word name, or "binomial," for each animal kind. These two-word names distinguish the species unmistakably from each other because although the same word, *familiaris*, may be used for several or even many different species it is never used for more than one species in any given genus, and the genus name is never used for more than a single genus. So that *Canis familiaris*, the scientific two-word name for the dog species, unmistakably distinguishes the dog by name from all the other half million species of animals we know. There might be a *Merula familiaris*, or a *Musca familiaris* in the list, but not a second *Canis familiaris*. You will have noticed that we have capitalized the first or genus word in the two-word scientific name of the dog, but not the second or species word. And this is the rule in zoological nomenclature. Even if the species word is derived from a proper name, as is often the case, it is not capitalized. The botanists do not adhere to this rule, so that they might write *Canis Browni*, if *Canis* were the genus name of a plant and *Browni* the species name.

Just as there are often several and sometimes many species sufficiently alike, or better, closely enough related, to be grouped together into one genus, so there are usually several or many genera related closely enough to be brought together into a group of a higher or more comprehensive degree. There are, for example, other genera of animals showing unmistakable affinities, by their resemblances of structure, with the dog and wolf genus *Canis*. Such for example are the genera *Vulpes* and *Urocyon* which include various species of foxes. These related genera are then grouped together to form a family; in this case the family *Canidæ*. Note that the proper name of this family is made by adding *idæ* to the stem part of the name of one of the genera in it. That is, the name of an important genus in the family is taken in the genitive case and pluralized in order to make the family name. And this is a general rule in zoological nomenclature.

Related families are grouped together to form orders.

Plainly related to the *Canidæ*, for example, are the *Felidæ*, or cats and cat-like animals, the *Ursidæ*, or bears, *Mustelidæ* or weasels, and some other families all of whose members are carnivorous in habit and have teeth, feet, and other parts specially modified in connection with this habit. All of these families then are grouped together to form the order *Carnivora*. All the families of hoofed animals, as the *Equidæ* or horses, the *Bovidæ* or cattle, the *Cervidæ* or various deer kinds, and other similar families, compose the order *Ungulata*. But all the animals of both *Carnivora* and *Ungulata* as well as of a number of other orders agree in possessing certain important common characteristics of structure and physiology, which undoubtedly indicate a certain relationship. And so they are grouped together to form a *class*. The particular class comprising the orders just spoken of is named the *Mammalia*, from the possession by all of its members of milk glands for producing milk for their young.

Finally there is a plain relationship among the class *Mammalia* or mammals, and the class *Aves*, or birds, the class *Reptilia*, or reptiles, the class *Amphibia*, or batrachians and the class *Pisces* or fishes. They are all back-boned animals, while other animals are not. They may be grouped together into a single large group called a branch. The name of this branch is the *Chordata*. There are eleven other branches in the animal kingdom, all of which are named and divided into their classes in the table on pages 55 to 57.

The branches are the largest groups used in the classification of animals, so that if we should now tabulate the scientific classification of our dog we should find it to belong to the

kingdom Animalia
branch Chordata
class Mammalia
order Carnivora
family Canidæ
genus Canis
species familiaris.

Its scientific name is, however, simply *Canis familiaris*, which indicates, to a zoologist, the whole classification of the dog.

Because as there is but one animal genus named *Canis* and that is a member of the family Canidæ, which in turn is a member of the order Carnivora, which is a member of the class Mammalia, which, finally, belongs to the great branch Chordata, we have indicated all the superior groups by naming the generic one only, and have pointed out what particular species of that genus we are referring to, when we simply say or write *Canis familiaris*.

There are many rules of custom which zoologists try to follow in deciding on names for new kinds and groups of animals, but they are too many and too technical to discuss here. However it is worth while to point out that while the scientific name of an animal may be more or less descriptive by the meaning of its genus and species words, it is not necessarily so. *Canis familiaris* is, translated, the common dog; *Canis latrans*, the barking dog; and *Canis occidentalis* the western dog, which are all therefore names of descriptive nature. But there might be a wolf named *Canis smithi*, which would not describe it at all. The name however would be a perfectly proper scientific name. There are indeed hundreds of scientific names which have no or almost no descriptive significance at all; and some that are even wrongly descriptive. For example a Russian naturalist might find in the wilds of Siberia a new kind of wolf, larger than any other kind known. He might name it therefore, descriptively, *Canis maximus*, the largest wolf. In the next year an American naturalist might find a still larger species in the heart of Alaska. But the name *Canis maximus* would always be used for the smaller Siberian wolf, because the scientific name is primarily a symbol, an arbitrary name, and not a description. And also the advantage of having the first name applied to a species retained for all time is very great. The stability of the system and its convenience depend largely on the custom of not changing the names unless absolutely necessary because of some original mistake in assigning the species to a wrong genus, or the necessity of dividing too bulky genera into smaller ones.

Branches and Classes of Animals.—The following table gives the names and arrangement of all the branches and classes of

the animal kingdom. No attempt should be made now to memorize this table.

ANIMAL KINGDOM

Branch I. PRŌTOZŌ'A (one-celled animals)

Class I. *Rhizŏp'oda* (amœba, *Heliozoa*, *Radiolaria*, *Foraminifera*, et al.).
Class II. *Mycētozō'a* (slime-moulds).
Class III. *Mastigŏph'ora* (whip-bearers, *Euglena*, trypanosomes, *Spirochæta*, et al.).
Class IV. *Spŏrozō'a* (parasitic Protozoa such as *Plasmodium* which causes malaria, *Babesia* which causes Texas fever of cattle, et al.).
Class V. *Infusō'ria* (mostly free-swimming Protozoa provided with cilia, *Paramœcium*, *Vorticella*, et al.).

Branch II. PORĬF'ERA (sponges)

Class I. *Porifera* (sponges).

Branch III. CŒLĔN'TERĀ'TA (sē-lĕn-te-rā'-ta)

(Aquatic, mostly marine, radially symmetrical animals having a combined body and stomach cavity)

Class I. *Hȳdrozō'a* (fresh water hydra, marine hydroids, many of the small jelly-fish, a few stony corals, et al.).
Class II. *Scyphŏzō'a* (sī-fō-zō'-a) (most of the large jelly-fishes).
Class III. *Actĭnozō'a* (sea-anemones; most of the corals, et al.).
Class IV. *Ctĕnŏph'ora* (tĕn-ŏph'-o-ra) (the comb- jellies, or sea-walnuts).

Branch IV. PLĂTYHĔLMĬN'THES (flat-worms)

Class I. *Turbellar'ia* (planarians, et al.).
Class II. *Trēmatō'da* (liver-flukes, et al.).
Class III. *Cĕstō'da* (tape-worms).

Branch V. NĔMATHĔLMĬN'THES (round-worms)

Class I. *Nĕmatō'da* (trichina, hookworms, et al.).
Class II. *Nĕmatōmŏr'pha* (horse-hair snakes, or cabbage-snakes, et al.).
Class III. *Acanthocĕph'ala* (thorn-headed worms).
Class IV. *Chætŏg'natha* (kē-tŏg'-na-tha) (arrow-worms).

BRANCH VI. TROCHELMĬN'THES (wheel-worms)

Class I. *Rotif'era* (wheel animalcules).

BRANCH VII. MŎLLUSCOI'DA
(small animals which are more or less mollusc-like)

Class I. *Pŏlyzō'a* (moss-animals).
Class II. *Phŏrŏ'nida* (worm-like animals living in sand).
Class III. *Brăchiŏp'oda* (lamp-shells, small marine animals with a bivalve shell).

BRANCH VIII. ECHĬNŎDĔR'MATA
(radially symmetrical, marine animals with a rough or spiny skin)

Class I. *Asteroi'dea* (starfishes).
Class II. *Ophiuroi'dea* (brittle-stars).
Class III. *Ĕchīnoi'dea* (sea-urchins).
Class IV. *Hŏlothuroi'dea* (sea-cucumbers).
Class V. *Crĭnoi'dea* (sea-lilies, or feather-stars).

BRANCH IX. ANNĔL'IDA (segmented worms)

Class I. *Archiannĕl'ida* (marine worms living in the sand).
Class II. *Chætŏp'oda* (earthworms, *Nereis*, et al.).
Class III. *Gĕphyrĕ'a* (jĕf-e-rē'-a) (marine worms of uncertain relationship, with little or no traces of segmentation in the adult).
Class IV. *Hĭrudĭn'ea* (leeches)

BRANCH X. ARTHRŎP'ODA
(animals with the body more or less distinctly segmented and with jointed appendages)

Class I. *Crustā'cea* (crayfish, lobsters, crabs, shrimps, et al.).
Class II. *Onychŏph'ora* (slime-slugs).
Class III. *Myrĭăp'oda* (myriapods, centipedes, et al.).
Class IV. *Insĕc'ta* (insects).
Class V. *Arăch'nida* (scorpions, spiders, mites and ticks).

BRANCH XI. MŎLLŬS'CA
(bilaterally symmetrical, unsegmented animals, most of which have shells)

Class I. *Amphĭneu'ra* (chitons, et al.).
Class II. *Gastrŏp'oda* (snails, slugs, et al.).
Class III. *Scaphop'oda* (tooth-shells).
Class IV. *Pĕlecўp'oda* (clams, mussels, oysters, scallops, et al.).
Class V. *Cĕphalŏp'oda* (squids, octopods and nautili).

Branch XII. CHORDĀ'TA

(animals that have a notochord at some stage of their development)

Class I. *Adēlochor'da* (balanoglossids, et al.).
Class II. *Urochor'da* (ascidians, et al.).
Class III. *Leptocard'ii* (lancelets).
Class IV. *Cyclostōm'ata* (lampreys and hagfishes).
Class V. *Pĭscēs* (pĭs-sēz) (fishes).
Class VI. *Amphīb'ia* (frogs, toads, salamanders, water-dogs, et al.).
Class VII. *Reptīl'ia* (snakes, lizards, turtles, alligators, et al.).
Class VIII. *Ā'ves* (birds).
Class IX. *Măммāl'ia* (mammals).

CHAPTER IX

SPONGES, AND SPONGE FISHING

The sponges are fixed, aquatic, plant-like animals living mostly in salt water. They are regarded as representing the simplest type of Metozoan body structure and cell specialization, and are classified as a branch of the animal kingdom called Porifera. The body of the simplest sponges is vase-shaped or cylindrical with the base attached to a rock or shell or other firm substance. At the free end there is an opening that leads down into the central cavity. The walls surrounding this cavity are perforated by numerous openings or canals through which the water flows.

Few sponges are of this simple vase-like appearance, however. Most of them are unsymmetrical, and cling close to the surface on which they grow, or form low compact bushy bodies looking much more like plants than like animals.

Sponges belonging to the genus *Grantia* are convenient types for study. They live in salt water and may be[1] obtained at many points on the Atlantic or Pacific Coasts on rocks, shells or other objects below low water line. They are subcylindrical in form, attached at the base, and with a rather large opening, the *exhalant opening*, or *osculum*, at the free end. All over the sides are numerous small openings leading into the *inhalant canals* which extend almost to the inner or *gastric cavity* or *cloaca*. Opening into the cloaca and extending almost to the outer wall are other canals, the *radial canals*. The inhalant and radial canals run side by side and communicate with each other by means of very small openings. The cells lining the radial canal are furnished with long lashes, or *flagella*, the lashing of which sets up currents of water which

[1] Inland schools can obtain specimens preserved in alcohol or formalin from dealers in natural history supplies.

passes in through the inhalant canals and through the small openings into the radial canals on into the cloaca and out through the exhalant opening at the free end of the sponge. The cells lining the radial canals and the cloaca take up and digest particles of food that are brought in by the currents of water. Some of this digested food is passed by osmosis to the adjacent cells which do not take up any food. Here we see a simple step in physiological division of labor. The outer cells,

FIG. 13.—A group of vase-shaped sponges, *Leucandra apicalis*. (Natural size.)

which compose the *ectoderm,* or outer skin, serve to protect the animal, while the inner cells, which make up the endoderm, digest the food and feed the other members of the colony. The currents that bring the food also bring fresh oxygen in the water. Some of this is taken up by the cells, while the carbon dioxide and other waste products that they excrete are carried away by the same currents.

Between the ectoderm and the endoderm, and pierced by

the inhalant and radial canals, is the soft gelatinous-like layer, the *mesoderm*, that is composed of various kinds of cells. Some of these are concerned in the formation of the spicules that make up the framework, some are concerned with digestion and some with reproduction. Two or three kinds of spicules may be found in the mesoderm of *Grantia*. They are composed of carbonate of lime, and are very brittle when dry. The framework of the commerical sponges is composed of exceedingly fine flexible fibers of a horny substance called *spongin*. This is the part of the animal that we commonly know as the sponge in the market.

Grantia reproduces itself in two different ways. Small buds sometimes appear on the external surface of the body which develop into small individual sponges. These gradually increase in size and finally break away from the parent and attach themselves to some other substance. In the more complex sponges these buds do not break away, but remain attached so that in time there is built up a complex sponge colony.

Besides this method of reproducing asexually, that is, without the union of two kinds of germ cells, all sponges have a mode of sexual reproduction. The male, or sperm, cells and the female, or egg, cells are produced in the same individual. The sperm cells when ripe are cast into the water and swim about until they come in contact with egg cells which they fertilize. From these fertilized egg cells sponge embryos develop which, after they have reached a certain stage, swim away by means of many cilia which cover their bodies and finally attach themselves to some substance where they remain the rest of their lives.

Sponges of Commerce.—All sponges have the same general type of structure but most of them branch extensively and form immense colonies with innumerable canals and cavities making altogether a complicated network. The sponges that we use are really only the skeletons of some of these great colonies with all of the soft parts dried or squeezed or washed out. Bleaching powders or acids are sometimes used to lighten the color, but they are apt to injure the fibers. The

best sponges come from the Mediterranean. This region annually produces about $2,000,000 worth of sponges, which is more than half the value of the product of the sponge fisheries of the world. Some sponges come from the Red Sea, others from the Bahama Islands, West Indies, the west coast of Florida and other places. The annual output from the Florida sponge fisheries is valued at between $500,000 and $600,000. The commercial sponges do not live in very deep

FIG. 14.—A common bath sponge. (Reduced.)

water, being usually found not deeper than 200 feet. In shallow water they are dragged from the rocks by men in boats who use long poles with hooks on the ends. Those growing in deeper water are dredged up or brought up by divers.

Many of the best sponge-fishing grounds have suffered very severely from destructive methods of fishing and efforts are now being made to protect these beds and to stock others. Several methods of sponge culture have been tried, most of

them with little or no success. The United States Bureau of Fisheries has found a method that it believes to be practicable. Live sponges are cut into small pieces which are fastened on some firm support and placed in suitable places. In from four to six years these fragments grow to a good marketable size.

Boring Sponges.—Among the most interesting and important of the sponges are the boring sponges which live on shells, spreading over the surface at first but eventually penetrating the shell in every direction, completely honeycombing it, and causing it to break up. They thus help to dispose of the shells of dead molluscs which would otherwise accumulate in vast quantities. They also attack shells in which the animals are still living and by boring through the shell greatly irritate the host which must constantly secrete new shell to close up the holes made by the intruder. These boring sponges are often serious pests in the oyster beds. The pearl-shell fishermen sometimes find some of their largest and otherwise finest shells completely ruined by the work of some of them.

Classification.—There is only one class belonging to the branch *Porifera* (L. *porus*, pore; *fero*, to bear) and that, too, is called *Porifera*. It is divided into two sub-classes, the *Calcarea*, including those sponges with a skeleton of calcareous spicules, and the *Non-calcarea*, with the skeleton either absent or composed of spongin fibers or of siliceous spicules. *Grantia* is an example of the sub-class Calcarea; the commercial sponges, the boring sponges, and indeed most of the others, belong to the Non-calcarea.

CHAPTER X

CORALS, SEA-ANEMONES AND JELLY-FISHES

Like the sponges, most of the polyps, and jelly-fishes, composing the branch Cœlenterata (Gr. *koilos*, hollow; *enteron*, intestine) are found in the sea. Those who live near the sea-

Fig. 15.—Sea-anemones. The middle specimen expanded and feeding; lower specimens partly or wholly contracted and with disk closed.

shore are familiar with the many-colored, flower-like sea-anemones that cover the rocks in shallow water, and with the clear transparent medusæ or jelly-fishes, which truly look like masses of animated translucent jelly. Less familiar are

the little tree-like hydroids that are found on the submerged rocks or shells along the shore at all depths. These little animals look so plant-like that they are often called zoophytes, or plant-animals, a name that is also applied to other polyps. Many of them however live a part of their lives as active, free-swimming forms before they settle down to become attached to the places where they are to remain. In the shallow waters of all tropical seas the coral polyps grow in such numbers that their myriad skeletons form whole groups of little islands and great projecting barrier reefs that may reach for miles along the shores. The great barrier reef off the north shore of Australia is more than a thousand miles long. Only a few of the polyps live in fresh water. Hydra, which is found in nearly all fresh water ponds or streams, is the most familiar example, and has already been studied.

Hydroids and Jelly-fishes.—In each of the four groups, or classes, into which the polyps and jelly-fishes are divided there are many modifications of the simple type plan presented by Hydra. If the buds that develop on Hydra should remain attached and continue to grow and in turn produce other buds, there would soon be developed a tree-like colony with a Hydra-like animal at the end of each branch. Some marine animals are developed in just this way, and are known as hydroids. The class *Hydrozoa* (Gr. *hydor*, water; *zōon*, animal) to which these belong includes the Hydra and other Hydra-like animals. The Hydrozoan colonies may be made up of two kinds of individuals, or *zooids*. One kind, known as the nutritive zooids, or polyps, retains much of the general appearance of the Hydra; the other kind, known as the reproductive zooids, or medusæ, develops into quite different looking animals. The medusæ are produced by budding off from the bases of the polyps. They are umbrella-shaped, jelly-like masses and are commonly known as jelly-fishes. After budding off from the polyps they float and swim in the water for some time and finally produce egg cells and sperm cells. From each fertilized egg a new individual develops. This new individual is at first an active free-swimming larva, called *planula*, which does not resemble either a medusa or a polyp. After a while

it settles down, becomes fixed, and develops into a polyp. Thus a polyp may produce a medusa or jelly-fish which, however, produces not a new jelly-fish, but a polyp. This is called an *alternation of generations*, and is not an uncommon phenomenon among the lower animals. It results from such an alternation of generations that a single species of animal may have two distinct forms. This having two different forms is

FIG. 16.—A jelly-fish, or medusa, *Gonionema vertens*, eating two small fishes. (From specimen from Atlantic Coast.)

called *dimorphism*. Sometimes, indeed, a species may appear in more than two different forms; such a condition is called *polymorphism*.

The Portugese man-of-war, common in tropical seas, is a representative of another group of this class. It appears as a delicate bladder-like float, brilliant blue or orange in color, usually about six inches long, and bearing on its upper

surface, which projects above the water, a raised parti-colored crest, and on its under surface a tangle of various appendages, some thread-like and others in grape-like clusters of little bell- or pear-shaped bodies. Each of these parts is a peculiarly modified polyp- or medusa-zooid, produced from budding from an original central zooid. Many other kinds of colonial jelly-fishes occur which show similar differences among the different members of the colony. Some individuals enable it to move through the water, some protect the colony, others procure or digest food and still others are modified into reproductive organs. The whole colony, or compound animal, floats or swims at the surface of the water and performs all the necessary functions of life as a single animal composed of organs might.

Most of the common large jelly-fishes belong to a second group (class *Scyphozoa:* Gr. *skyphos,* cup; *zōon,* animal). They often occur in great numbers on the surface of the ocean. Others live in deeper waters, a few having been dredged up from depths of even a mile below the surface. The umbrella-shaped bodies vary in size from less than an inch to more than six feet in diameter. From the underside of the central part of the body hangs a mass of long tentacles which are provided with stinging-threads. The small animals that become entangled in these tentacles, which sometimes reach a length of more than 100 feet, are stung by the stinging-threads and serve as food for the jelly-fish. The body substance of some jelly-fishes is more than 99 per cent. sea-water. Most of them are nearly transparent, but some are beautifully colored and many are phosphorescent.

Sea-anemones and Corals.—The most familiar examples of the polyps and jelly-fish branch of animals are the multi-colored sea-flowers, or sea-anemones, found along all ocean shores. The petal-like tentacles, that surround the central mouth-opening spread wide and seize and thrust into the mouth any small animals that may walk or swim into this living trap. Less common are the beautiful sea-pens, sea-feathers and sea-fans which are closely related to the sea-

anemones. All these belong to the class *Actinozoa* (Gr. *aktis*, ray; *zōon* animal).

To this class belong also the interesting coral polyps that are found in all tropical and sub-tropical seas. The individual coral polyps are not unlike the sea-anemones in general appearance and structure, but they usually live in great colonies, forming large irregular or branching tree-like masses. As the animals grow they secrete a strong skeleton of carbonate of lime. The corals with which most of us are familiar are

FIG. 17.—Branching coral, *Acropora muricata*, from Samoa. (Much reduced.)

really only the calcareous skeletons of innumerable little polyps. The living coral is quite different in appearance from this hard stony skeleton. The surface is often soft and velvety, pink, green, yellow, brown or purple, and covered with the small waving tentacles of the numerous little polyp individuals that make up the colony. As each individual polyp dies and leaves its skeleton it is adding its small mite toward the formation of the great coral rocks or reefs or islands characteristic of the tropical seas. Coral polyps usually do not live

more than fifteen or twenty fathoms below the surface of the water, so we find the reefs as fringing reefs lying attached to some shore line, or as barrier reefs, lying a little further out and separated from the land by an intervening lagoon. Or they may be in the condition of atolls, which make up groups of small coral islands, each surrounding a more or less circular or oval lagoon. These coral islands are themselves often protected by barrier reefs. The foundations upon which the coral atolls rest are probably the summits of submarine mountains which come to within 100 or 150 feet of the surface. On such places coral polyps and many other kinds of marine animals and plants grow, and accretions due to these and other substances slowly raise the bank toward the surface of the water, so that at low tide the tips of the growing branches of the coral may be above the surface. As the coral is broken and ground into fine bits by the action of the waves and as other pieces are washed higher on top of these, the island gradually rises above the level of the tides. The waves continue to break up some of the coral into fine particles, that, together with other débris, forms a little calcareous soil in which may germinate the seeds carried to it by birds or ocean currents. With the growth and decay of vegetable life the soil gradually becomes more fertile, until finally the islands may become covered with a luxuriant plant growth which in turn serves as the home of many insects and birds and other animals.

There are over 200 kinds of coral polyps known. Many kinds are used for ornaments or decoration. The red coral, which grows chiefly in the Mediterranean, is much used for jewelry. The rose-pink coral is very valuable, some of the finest kinds selling for hundreds of dollars an ounce.

To the class *Ctenophora* (Gr. *kteis*, comb; *phero*, bear) belong a few peculiar delicate, transparent, medusoid jelly-fish, swimming by means of the rhythmical beating of several rows of vibratile plates and not by means of the motion of the bell or umbrella as in the case of other jelly-fishes.

CHAPTER XI

THE LIVER-FLUKES, TAPE-WORMS, AND OTHER PARASITIC FLAT WORMS

The Worms.—In the older classifications the name Vermes was applied to a large group of worm-like creatures which resembled each other in some respects, but as these animals came to be better known it was found that some were not at all closely related to others and it became necessary to divide the group into five smaller groups of equal rank, the flat worms (Platyhelminthes,) the round worms (Nemathelminthes), the rotifers (Trochelminthes), the sea-mats and lamp-shells (Molluscoidea) and the segmented worms (Annelida). These all differ from the polyps and sponges by being bilaterally symmetrical and in having three well-developed layers of cells in the body-wall, the mesoderm being well developed. Usually, also, the various systems of organs are much more complex, and the individuals do not form colonies.

The first group (the branch Platyhelminthes; Gr. *platus*, broad, *helmins*, worm) includes the liver-flukes, tape-worms and other parasitic flat-worms, and a few free-living flat worms that live in fresh water or salt water, or, more rarely, on land. They are usually much flattened and without true segmentation, although the bodies of the tape-worms have a jointed appearance owing to their being largely made up of a string of reproductive units. Many of the parasites have very complex life histories and live in different kinds of animals while passing through their successive stages of development.

Fresh-water Planarians.—In the mud at the bottom of ponds of fresh water or clinging to the rocks or sticks in such places are often found small flat creatures that are known as planarians. They look somewhat like small leeches, which belong to the branch Annelida, but may be distinguished

from them by the absence of rings around the body. These planarians are less than half an inch long, very thin and rather broad. On the upper surface near the front is a pair of pigmented spots which are probably sensitive to light and are called the eyes. The mouth is on the under surface a little behind the middle of the body. The alimentary canal is composed of three main branches, each with numerous small side branches. One main branch runs forward from the mouth, and the other two run backward, one on each side of the body. There is no anal opening, and the alimentary canal thus forms a system of fine branches closed at the tips, and extending all through the body. The nervous system is composed of a ganglion or brain in the front end of

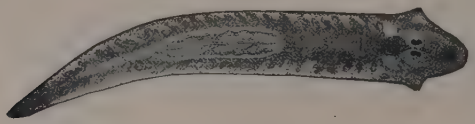


FIG. 18.—A fresh-water planarian, *Planaria* sp. (Eight times natural size; from a living specimen.)

the body from which two main branches extend back throughout its whole length. From these main longitudinal branches arise many fine lateral branches.

Many beautiful and interesting members of the class Turbellaria—the class to which the planarians belong—are marine and a few are found in moist earth.

Liver-flukes.—The liver-flukes, *Fasciola hepatica*, live as parasites in the liver of sheep and cattle, especially the former. In Europe they sometimes kill hundreds of thousands of sheep annually, and they have more recently become of some importance in the United States, the Pacific and the Gulf Coast regions suffering most. They are interesting not only on account of their economic importance but because they furnish a good example of a Metazoan parasite that requires two different kinds of hosts in which to complete the different stages

of its development. The adult fluke, which occurs in the sheep's liver, has a flattened leaf-like body, and is from three-quarters of an inch to more in length. There are two suckers on the ventral side, one surrounding the mouth, the other nearer the anterior end. Their presence in the liver produces a disease known as liver rot because the tissues of the liver degenerate. Affected sheep often die.

The flukes are hermaphroditic, and each individual is capable of producing about five hundred thousand very minute eggs. These pass through the bile ducts of the host into the alimentary canal and thence with the excrement to the ground. If the eggs fall on dry ground they usually perish, but if they fall on damp herbage or in water there hatch from them small ciliated larvæ. These swim about in the water for ten or twelve hours, and, if they do not happen to come in contact with a certain kind of snail, they perish. Those that do succeed in finding a snail bore their way through any of the soft parts into the body, where they undergo certain changes, finally forming sporocysts within which are developed small larvæ called *rediæ*, which in turn produce other rediæ. The rediæ finally give rise to certain heart-shaped bodies each with a long flexible tail. These are called *cercariæ*, and in this shape the parasites issue from the snail host. Soon after leaving the snail the cercariæ become encysted and within the cyst further changes take place, the animal becoming more like a minute adult fluke. If these cysts are swallowed by a sheep when it is eating grass or drinking water where they occur, the cyst is dissolved by the digestive juices in the sheep's stomach and the young flukes are liberated. They soon work their way from the stomach to the duodenum and through the bile duct into the liver, where they develop into the adult flukes.

FIG. 19.—Liver-fluke, *Fasciola hepatica*. (Nearly twice natural size.)

It will be seen that under ordinary conditions there is little

chance of many of the thousands of eggs that are produced by the adult fluke ever meeting successfully all the dangers that beset their path. The eggs may fail to reach the water; or if hatched the larvæ may not be able to find a snail; or if the snail is found it may be destroyed before they have completed their transformations. The cercariæ are always in danger of being eaten by aquatic animals while in the water, or if not eaten after they form their cysts the particular blade of grass to which they are attached may never be eaten by a sheep. Yet the number of eggs that are produced is so great that hosts of the young flukes do successfully overcome all their difficulties and infect so many sheep that they become an important economic factor in sheep-raising in many regions.

With a knowledge of the life history of the parasite, however, it is a comparatively easy matter to prevent the infection of the sheep. This is accomplished by keeping them away from land subject to overflow, or where the snails occur in numbers. Springs and other watering places are particularly dangerous when there are many snails about them.

This same species of liver-fluke, *Fasciola hepatica*, sometimes occurs in cattle, horses and other domestic animals and even, although very rarely, in man.

Other Flukes.—The large American fluke, *Fasciola magna*, which is often a serious pest of cattle in the Southern states, also occurs in the deer, which was probably its original host. The life history has not yet been worked out, but it is probably somewhat similar to that of the liver-fluke of sheep. Another species of fluke is common in ducks, and many other animals may be more or less seriously affected by still other kinds. One species occurring in Egypt is a dangerous parasite of man, infesting the urinary and abdominal blood-vessels where it causes serious inflammation. The infection is probably from bad water.

Some species are external parasites and attach themselves to their hosts by means of a series of suckers. One kind that attaches itself to the gills and fins of fresh-water fishes is viviparous, that is, it brings forth its young alive, and the embryo, before it is extruded, itself contains another embryo

and this in turn still another embryo so that three generations of embryos are present one within the other.

Tape-worms.—The tape-worms are the most common and the best known of the flat worms. There are many species, the adults of all of which live in vertebrate animals. But there is almost always an alternation of hosts during the life of the parasite, the larval tape-worm living in one animal and the adult in another. In the larval stage the tape-worms may occur in various parts of the body of the intermediate host, but the adult or fully developed worm always occurs in the alimentary canal of the final host. Many of the domestic animals suffer from these parasites. At least ten different species of tape-worms have been found in the dog, the intermediate hosts including rabbits, sheep, and other animals that the dog may feed on. Many of the domestic fowls are infected by tape-worms, whose intermediate hosts are insects or small aquatic crustaceans, like *Cyclops*.

Several kinds of tape-worms infest man. *Tænia solium*, whose intermediate host is the pig, may serve as an example of the group. The adult worm is attached to the inner wall of the intestine of man by a number of fine hooks with which the small head is provided. The long, ribbon-like, symmetrical body lies free in the alimentary canal, where it absorbs the liquid food directly through its thin body-wall. The parasite has neither mouth nor alimentary canal. The body may reach a length of many feet and be composed of as many as 850 segments, or *proglottids*. Each proglottid produces both sperm cells and egg cells, and as these become mature the posterior proglottids drop off one by one and pass out of the alimentary canal with the excreta. If some of these escaped proglottids are eaten by a pig the embryos issue from the eggs, bore through the walls of the alimentary canal of the host, and make their way to the muscles, where they increase greatly in size and develop into a rounded sac filled with liquid. In this stage they are large enough to be readily seen, and the infected spotted meat is called "measly pork." If such infected pork is eaten by man without being cooked sufficiently to kill the parasites, the young tape-worms will attach themselves to the

FIG. 20.—Some segments of the tape-worm, *Tænia saginata*, from man. (About natural size.)

walls of the alimentary canal and soon develop into the many-jointed adult. Tape-worms cause much trouble, especially to children.

It is probable that the most common tape-worm affecting man in the United States is one that passes its intermediate stage in cattle. It is known as *Tænia saginata*, and is much like *T. solium*, but the head is depressed instead of being convex at the end, and the hooks, which are conspicuous in *T. solium*, are wanting in *T. saginata*.

It is plain that either one of two things is necessary to prevent infection; all meat must be carefully inspected and any that is "measly" rejected, or it must all be so thoroughly cooked that there will be no chance for any of the encysted forms to remain alive.

FIG. 21.—Head of tape-worm, *Tænia saginata*. (Highly magnified; after Wood.)

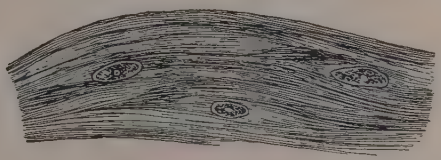


FIG. 22.—A piece of a muscle of the ox, with three specimens of the tape-worm, *Tænia saginata*, in encysted stage. (Natural size; after Osterberg.)

If a child or an older person becomes infested a physician should be consulted, as many of the vermifuges that are often recommended are unsafe.

A serious disease of sheep, known as *gid*, is caused by the cysts, or "bladder-worms," of a tape-worm, *Multiceps multiceps* (*Cœnurus cerebralis*), the adult stage of which is passed in the intestine of the dog. The proglottids pass from the dog in the feces and the eggs are released and splashed on the grass or washed to pools where the sheep drink when the rains come. When the eggs are taken into the stomach of the sheep the embryo is released and makes its way into the blood-vessels and

finally to the central nervous system. In the brain it grows rapidly to the size of a hazelnut, or larger, the sheep, of course,

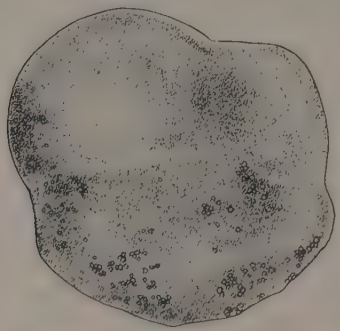


FIG. 23. -The gid parasite, *Multiceps multiceps*, in bladder-worm stage from brain of sheep. (Much reduced; after Hall.)

suffering from the movements of the parasites and their presence in the brain. The infected sheep usually dies and when its brain infested with the "bladder-worms" is eaten by

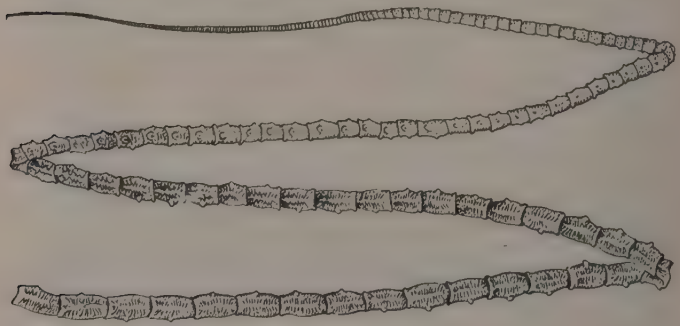


FIG. 24.—Adult gid tape-worm, *Multiceps multiceps*, from the intestine the dog. (Natural size; after Hall.)

a dog or some other carnivore many more tape-worms are produced in the new host.

This disease has been a serious scourge of sheep in Europe for centuries, and for a long time has existed in Montana where the loss is at least $10,000 every year. The number of the parasites may be partially controlled by keeping only a few dogs around the sheep or in regions where they are feeding, and by keeping these dogs free from tape-worms. The dogs should never be allowed to feed on the carcasses of the sheep that have died from the disease, nor is it well to let them feed on the heads of slaughtered sheep that may be infected.

Classification of the Flat-worms.—The *Platyhelminthes* are divided into three classes, the *Turbellaria*, the *Trematoda*, and the *Cestoda*. Another class, the *Nemertea*, is sometimes included in this branch, but its relation is doubtful. Its members are of no economic importance.

The *Turbellaria* (L. *turbellæ*, disturbance) are mostly non-parasitic and have the epidermis covered with cilia. The fresh-water planarians are examples.

The *Trematoda* (Gr. *trēma*, perforation; *eidos*, likeness) are all either external or internal parasites. The life history, especially of the internal parasites, is often very complicated, as we have seen in our study of the liver-flukes.

The *Cestoda* (Gr. *kestos*, a girdle, *eidos*, likeness) are all internal parasites in whose life history there occurs a tape-worm stage in a vertebrate host and a bladder-worm stage in a vertebrate or invertebrate host. The tape-worms of man and of other animals are examples of this class.

Parasites and Pearls.—After calling attention to so much harm that these lowly parasites may cause it is only fair that a paragraph should be given to pointing out how a few of them are of some service to man. For a long time it has been known that the pearls that are found in many molluscs are secretions formed about foreign particles that have found their way inside the shell. It is now known that the larvæ of several Trematode and Cestode worms are the objects around which some of the finest pearls are formed. The Trematode larvæ are most common in mussels, while the Cestodes are found very abundantly in the pearl oysters of Ceylon and other parts of the world. The vertebrate hosts in these instances are

usually certain fish that feed on the molluscs. In these the adult parasite lives, and some of the young embryos that are set free in the water gain access to the gills, liver or mantle of the molluscs. Here many go on with their development until the mollusc is eaten by a fish and the life cycle is begun again. In some instances, however, the irritation due to the presence of the parasite causes a calcareous secretion, like that forming the shell, to be deposited around the parasite. This forms the nucleus of a pearl which grows by additional layers being deposited around it, the luster depending on the kind of mollusc in which it is found. "The most beautiful pearl is only the brilliant sarcophagus of a worm."

CHAPTER XII

TRICHINA, HOOKWORMS, FILARIA, AND OTHER PARASITIC ROUND-WORMS

The large group of hair-like or thread-like unsegmented worms, constituting the branch Nemathelminthes (Gr. *nēma*, thread; *helmins*, worm), includes certain kinds which on account of their parasitic habits are of very great economic importance. Perhaps the most familiar examples of the branch are the hair-worms, or horse-hair snakes, which are often found in watering troughs or pools of water. Because of their remarkable appearance many persons believe them to be horse-hairs that have dropped into water and changed into these animals. They really come mostly from the bodies of insects in which they pass a part of their lives as parasites. The vinegar-eel, which is found in weak vinegar is another common example of the group.

FIG. 25. vinegar-eel, *Anguillula* sp. (Greatly magnified; from a living specimen.)

Trichina.—The dreaded trichina, *Trichinella spiralis*, which causes the disease called trichinosis, is a minute round-worm the adults of which live in the intestine of man, pigs and other animals. These adults produce living young which bore through the walls of the intestine, and are carried by the blood, or otherwise make their way to the muscles, where they form little cells or cysts in which they lie. The presence in the muscles of thousands or millions of these little parasties often causes great suffering, sometimes death to the host. It has been estimated that the trichinosed flesh of a human subject may contain 100,000,000 of these encysted trichinæ. Before further development of

the worms can take place such trichinosed flesh must be eaten by another animal in which they can live. Pigs are probably usually infected by eating dead infected rats or scraps of pork that have been thrown out in garbage. Man is usually infected by eating trichinosed pork. In the alimentary canal of the new host the trichinæ escape from the cyst and after becoming sexually mature produce the young which migrate to the muscles again.

The close watch that the government inspectors keep over the meats that go out from all the great packing houses makes the dangers from all parasites of this kind very much less than it used to be. But the meat from the smaller slaughter houses is usually not inspected and is always a source of danger. No pork, either fresh or smoked, should be used without being thoroughly cooked in order that any trichinæ in it may be killed.

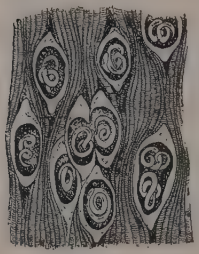


FIG. 26.—Encapsuled trichinæ in trunk muscle of pig. (Greatly magnified; after Braun.)

Eel-worms.—Belonging to the genus *Ascaris* are several round-worms, or "eel-worms," some of which are very common and of considerable economic importance. The large-headed thread-worm, *Ascaris megalocephala*, which occurs in the alimentary canal of the horse, reaches a length of from eight to sixteen inches and may be as thick as a lead pencil. The fertilized eggs of the parasites are passed from the body of the host with the excreta, and probably gain entrance to a new host through stagnant water or by a horse eating grass or leaves on which the eggs occur.

A similar but somewhat smaller species, *Ascaris lumbricoides*, occurs in man and in sheep and hogs. In children, particularly in tropical regions, these parasites may occur in large numbers, sometimes from one to ten hundred in a single individual. In such cases they may cause nervousness, irritability, hysteria or even convulsions. In some cases

the parasites may emigrate to other parts of the host, but ordinarily they remain in the alimentary tract.

The life history and mode of infection are similar to those of the preceding species. The eggs may be washed from the feces into drinking water, or they may become dry and be blown about as dust or become attached to fruit or vegetables. Soon after they reach the stomach of their host they begin their development. Strong vermifuges are necessary to remove them, but such medicines should be used only under the doctor's advice.

Still another species, *Ascaris canis*, is a very serious pest of dogs, especially puppies, and often causes serious losses to breeders of these animals. It occurs also in cats, lynxes and lions.

The stomach worm of sheep, *Hæmonchus* (*Strongylus*) *contortus*, is another important intestinal parasite belonging to the group. It is a very small thread-like species occurring in the fourth stomach of sheep, cattle and goats. The larvæ which hatch from eggs that pass out with the feces get on the grass blades and so into the stomach of new hosts. As the infection is direct the disease often spreads rapidly and does serious damage, particularly to lambs, which may die in considerable numbers.

Uncinariasis, or Hookworm Disease.—Perhaps no other disease has attracted so much attention in the United States during the past few years as the hookworm disease. It is caused by a small round-worm from one-half to four-fifths of an inch in length. On the anterior end, which is bent back giving it the suggestive hook shape, is the cup-like mouth by means of which the parasites attach themselves to the mucous membrane of the walls of the intestine, where, in addition to sucking the blood of the victim and affecting the mucous membrane, they produce a poison which may affect the host in a variety of ways. The most pronounced symptoms are anemia and aberrations of appetite. The skin becomes dry, waxy white, or dirty yellow, and the patient may eat too little or too much. In severe cases there seems to be an uncontrollable desire for such things as chalk, rotten

wood, sand, gravel and all kinds of dirt. This has given the popular name of "dirt eaters" to those affected with this parasite.

The myriad eggs produced by the adult hookworms pass out of the body of the host with the feces, and if these fall on the ground and the temperature and moisture conditions are suitable, as they usually are in the tropical and semi-tropical regions where this disease is worst, the young larvæ soon hatch and grow for a few days before they become encysted. In this latter condition they may remain for some time, even several months, until they are in some way introduced into a new host. There are two possible ways of infection, through the

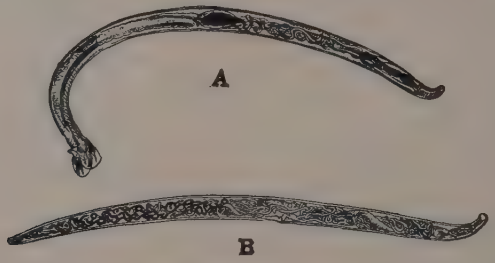


FIG. 27.—Hookworm, *Necator americanus*. *a*, Male; *b*, female. (Greatly enlarged; after Wilder.)

mouth or through the skin and the circulatory system. For a long while it was thought that infection was wholly through the mouth, but it is now known that this is not even the usual mode of infection. When the encysted larvæ come in contact with the skin of some person, such as the bare foot of a child, they break from their covering and burrow their way into the skin through some of the pores or hair follicles. They soon find their way into the circulation and later into the lungs or larynx and finally are swallowed and attach themselves to the walls of the alimentary canal.

In passing through the skin they produce certain symptoms commonly known as ground itch which often causes much suffering. It will be seen that children are, under ordinary

circumstances, more subject to attack than adults because they go barefoot more, but adults are in no wise immune, and in mining regions men may furnish the highest percentage of infection because conditions in the mines are favorable for the development of the parasite.

Epsom salts followed by thymol and then by epsom salts again will remove the worms from the body of the host, but reinfection may again take place unless sanitary measures are adopted to control the spread of the pest. Where the modern sewage facilities are found no hookworms occur, and the great fight that is being made against this, the worst curse of the poorer classes of the south, is made against the unsanitary

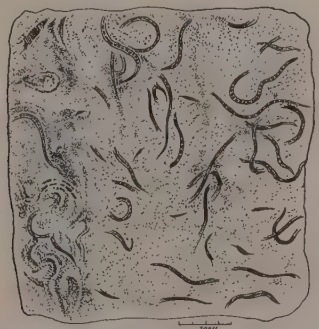


FIG. 28.—Section through the skin of a dog two hours after it has been infected with the Old World hookworm. (Greatly enlarged; after Wilder.)

conditions that exist in many regions. If the soil is not polluted with the feces that contain the eggs of the parasite the disease will not spread.

Not only do the hookworms directly cause many deaths each year, but they lower the vitality of the victims so that they become an easy prey to other diseases. In addition they retard their physical and intellectual development, seriously affect the working capacity and in many other ways

exert a baneful influence on the general health and longevity and on the material welfare of the people.

Porto Rico has suffered severely from this disease, as indeed have nearly all tropical and sub-tropical countries. In the old world the most common species of hookworm is *Uncinaria duodenalis*. In the United States *Necator* (*Uncinaria*) *americanus* is the most abundant. Both of these species were formerly included in the genus *Ankylostomum* and so the disease that they cause is frequently called ankylostomiasis.

Several of our domestic animals are infected with other species of hookworms. Uncinariasis, or "salt sick," or hookworm disease of cattle, is a very serious disease in some of the southern states. This disease can be partially controlled by intelligent methods of handling the stock. As it occurs chiefly on low wet lands the selection of pasture lands is of first importance, or rather it is of second importance, for the most important thing of all is to keep the disease out altogether by not allowing infected cattle to come on the farms or into the locality.

A species of hookworm occurring in fur seals often causes a loss of thousands of the young or pup seals each year on the breeding grounds.

Filaria and Elephantiasis.—Another genus of very serious Nematode parasites is known as *Filaria*. The filariæ cause the various forms of disease known as filariasis. *Filaria bancrofti* is the name of a minute, transparent, little worm that occurs in human blood and lymph in many tropical and sub-tropical regions, extending often into temperate climates. The larval forms, that occur in the blood, are but a little more than one one-hundredth of an inch long and about as big around as a blood corpuscle. During the day time but few of these are to be found in the blood near the surface of the body, but as evening comes on they may be found there in increasing numbers.

This night-swarming to the peripheral circulation has been found to be a remarkable adaptation in the life history of the parasite to the presence of night-flying mosquitos, for it has been demonstrated that in order to go on with their develop-

ment these larval forms must be taken into the alimentary canal of a mosquito. There they undergo certain changes, and then make their way through the walls of the stomach into the muscles, where they increase in size until they are about one-sixteenth of an inch in length. Later they migrate to other parts of the body, some of them to the proboscis of the mosquito from which they issue when the mosquito is feeding and thus gain entrance into another host. It is not known that these parasites can gain an entrance into the circulatory system in any other way, but it has been suggested that mosquitos dying in the water may liberate some of the filariæ which may later find their way into the vertebrate host when the water is used for drinking.

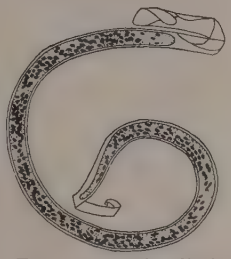


FIG. 29.—Microfilaria of the blood; immature stage of *Filaria bancrofti*. (Greatly enlarged; after Terzi.)

Soon after entering the circulatory system of the human host the parasites make their way into the lymphatics where they attain sexual maturity, and in due time new generations of the larval filariæ, or microfilariæ, are poured into the lymph, and finally into the definite blood-vessels, ready to be sucked up by the next mosquito that feeds on the patient.

In most cases of infection the presence of these filariæ in the blood seems to cause no inconvenience to the host. They are probably never injurious in the larval stage, that is, in the stage in which they are found in the peripheral circulation.

In many cases, however, the presence of the sexual forms in the lymphatics may cause serious complications. The most common of these is that hideous and loathsome disease known as elephantiasis, in which certain parts of the patient become greatly swollen and distorted. An arm or a leg may become swollen to several times its natural size, or other parts of the body may be seriously affected. This disease occurs most commonly in tropic and sub-tropic regions. Nearly one-third of the natives of the Samoan Islands suffer from elephantiasis.

The guinea-worm, *Filaria medinensis*, referred to on an earlier page, is a member of this group. It has been known for many ages, and is thought to be the "fiery serpent" mentioned by Moses. It lives in the connective tissues, where it attains a length of two or three feet. Its diameter is about one and one-half millimeters. When it is ready to produce young it usually descends to the feet or the lower part of the legs of the host or the part most likely to come in contact with the water. Here it burrows out to the surface, often producing serious sores. The intermediate stage is passed in the body of *Cyclops*, a small fresh-water crustacean.

There are several other species of *Filaria* that are parasitic in man but they are of less importance. *Filaria loa* is an interesting species that lives in the connective tissue just under the skin and travels about from one part of the body to another, occurring most commonly about the eyes, where their presence may cause irritation and congestion.

Classification of Nemathelminthes.—This branch may be divided into three classes, the *Nematoda*, *Nematomorpha* and *Acanthocephala*. The class *Chætognatha* (Gr. *chaitē*, hair; *gnathos*, cheek) or arrow-worms, is usually included in this branch but the relationship of the group is very uncertain.

The *Nematoda* (Gr. *nēma*, thread; *eidos*, likeness) are by far the most important and include all of the forms that have just been described, with the exception of the hair-snakes which belong to the second class.

The *Nematomorpha* (Gr. *nēma*, a thread; *morphē*, form) include the hair-snakes, the larvæ of which, as we have already noted, are parasitic in insects. One common species, *Mermis albicans*, frequently occurs abundantly enough in grasshoppers to be of some importance in their control. It is probably this species, too, that at times causes so much alarm in some regions when the "cabbage snakes" appear in great numbers. When these round-worms occur on cabbages or other vegetables it means that the insect that acted as their host was probably resting or feeding on the plant when the parasite left it. As soon as they can they pass into the ground

and do not injure the vegetables. No harm will come from eating vegetables that have been visited by these parasites.

The *Acanthocephala* (Gr. *akantha*, thorn; *kephalē*, head), or thorn-headed worms, include a number of parasitic forms which show extreme specialization in their mode of life. The anterior end is developed into a conspicuous spiny organ for holding on to the walls of the alimentary canal of the hosts in which they live. There is no mouth or digestive organs but the parasite takes its nourishment through the body-wall from the food surrounding it.

Echinorhynchus gigas, infesting hogs, is the best known species of this class. In America the larvæ of the June beetle, *Lachnosterna*, which is the common white grub found in the sod in pasture lands and elsewhere, serves as the intermediate host for the parasite. Hogs should not be allowed to pasture on lands where the grubs have become infected from previously infested hogs. Once pasture land has become infected it should be left for three years to insure the maturing of all the grubs that are infected.

Several other species belonging to this class are parasites of fishes.

FIG. 30.—A wheel animalcule, *Rotifer* sp. (Much enlarged; from living specimen.)

Animals of Uncertain Relationship

There are two groups of aquatic animals the exact relationships of which are by no means agreed upon by systematic zoologists. They are usually supposed to be more nearly related to the worms than to any other group, and as they are not of enough economic importance to be given a separate chapter they may be mentioned here.

The Wheel Animalcules, or Rotifers, Branch Trochelminthes (Gr. *trochos*, wheel; *helmins*, worm). These are minute aquatic animals which on account of their size were for a long time classed with the Protozoa. But they are really very complex in structure. The anterior end is provided with

a circlet of vibrating cilia, which has suggested the common name. These little animals are interesting on account of their remarkable power to withstand drying. When the water in which they are found evaporates, some of them do not die but, as minute shrivelled dust-like particles, may lie for months or even years and be revived again when water reaches them.

The Sea-mats and the Lamp-shells, Branch Molluscoida (*Mollusca*, mollusc; Gr. *eidos*, likeness).—The sea-mats, or *Polyzoa*, are common on rocks along the seashore and sometimes in fresh water also. Most of them either spread mat-like over the surface of the objects on which they are growing, or form branched tree-like or moss-like colonies and look much more like plants than animals. Only their development suggests any relation to the worms. The lamp-shells, or *Brachiopoda*, are all marine. They look so much like little clams that for a long time they were classed with the molluscs. Their chief interest lies in the fact that they represent a group of animals that were once very numerous but which have not been able to adapt themselves to the changed conditions that are found on the earth to-day. In ages past they seem to have occurred in great numbers, as more than a thousand species have been preserved as fossils in the rocks. To-day only about one hundred species are known, and some of these are very rare.

CHAPTER XIII

STARFISHES, SEA-URCHINS AND SEA-CUCUMBERS

The starfishes, sea-urchins, sand-dollars and sea-cucumbers, branch Echinodermata (Gr. *echīnos*, hedgehog; *derma*, skin), compose the only branch of animals all of whose members are exclusively marine. Although they are among the most common inhabitants of all sea beaches no species has adapted itself to life in fresh water. Why this is so no one is yet able to explain. Most of them can move about freely but some of the feather stars are attached to rocks or other objects as the polyps are.

The Starfish.—The common five-rayed starfish well illustrates the general plan of structure of members of this group. The five rays arranged around the central disk illustrate the *radial symmetry* which is characteristic of the branch. The entire *aboral* or upper surface, as well as a greater part of the *oral* or lower side, is thickly studded with the calcareous plates, or *ossicles*, of the body-wall. These ossicles support many short, stout spines arranged in irregular rows, and numerous pincer-like processes, the *pedicellariæ*. In the interspaces between the calcareous plates are soft fringe-like projections of the inner body-lining, the *respiratory cæca*. A little to one side of the center of the disk is the small striated calcareous *madreporic plate*, and a little nearer the center is the anal opening. At the tip of each arm or ray is a cluster of small calcareous ossicles and within each cluster a small speck of red pigment, the eye-spot or *ocellus*.

On the oral (under) surface are the centrally-located mouth, and the *ambulacral grooves* running longitudinally along each ray. In each groove are two double rows of soft tubular bodies with sucker-like tips. These are called the *tube-feet*, and are organs of locomotion.

By removing all of the dorsal body-wall except the part surrounding the madreporic plate and the anus, the internal

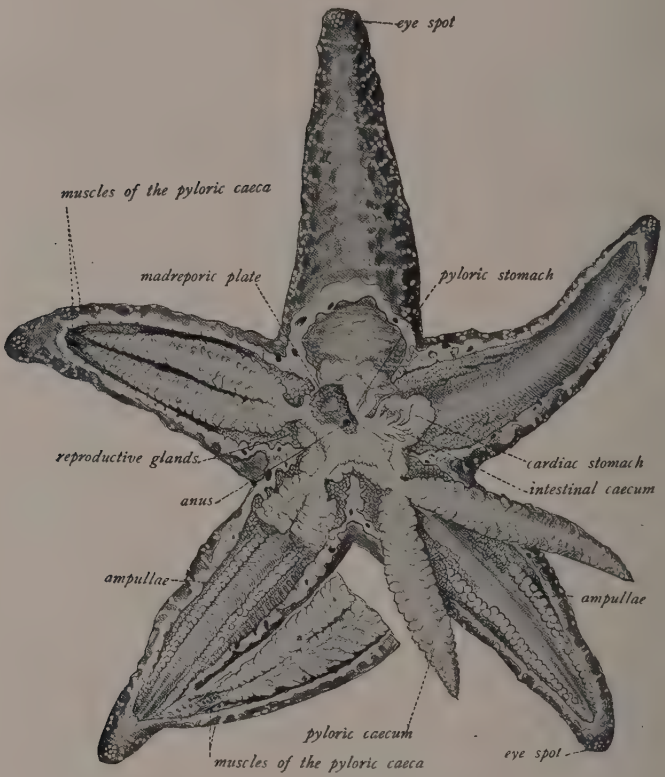


FIG. 31.—Dissection of a starfish, *Asterias* sp. male.

organs are exposed. The large *alimentary canal* is divided into several regions. The short esophagus leads from the

mouth directly into a large membranous pouch, the *cardiac* portion of the stomach. By a short constriction the cardiac portion is separated from the part which lies just above, *i. e.*, the *pyloric* portion of the stomach. From the pyloric portion large, pointed, paired glandular appendages, the *pyloric cæca*, extend into each ray. Their function is digestive, and sometimes they are spoken of as the digestive glands or "livers." The pyloric cœca, as well as the cardiac portion of the stomach, are held in place by paired muscles which extend into each arm. The pyloric portion of the stomach opens above into a short intestine which terminates in the anus. Attached to the intestine is a convoluted many-branched tube, the *intestinal cæcum.*

In the angle of each two adjoining rays are paired glandular reproductive organs, which empty by a common duct on the aboral surface. The small bulb-like bladders extending in two double rows on the floor of each ray are the water-sacs, or *ampullæ*, and each one is connected directly with one of the tube-feet.

Passing around the alimentary canal near the mouth is a ring-shaped canal from which the radial vessels run out beneath the floor of each ray and from which a hard tube extends to the madreporic plate. This hard tube is the *stone canal*, so called because its walls contain a series of calcareous rings, while the circular tube is the *ring canal* or *circum-oral water-ring*, from which radiate the *radial canals*. In some species of starfish there are bladder-like reservoirs, *Polian vesicles*, which extend interradially from the ring canal.

The ampullæ and tube-feet are all connected with the radial canals. By the contraction of the delicate muscles in the walls of the ampullæ the fluid in the cavity is compressed, thereby forcing the tube-feet out. By the contraction of muscles in the tube-feet they are again shortened, while the small disk-like terminal sucker clings to some firm object. In this way the animal pulls itself along by successive "steps." This entire system, called the water-vascular system, is characteristic of the branch Echinodermata. In addition to the fluid in the water-vascular system there is yet another body-

fluid, the *perivisceral* fluid, which bathes all of the tissues and fills the body-cavity.

The perivisceral fluid is ærated through the respiratory cæca which, as we have seen, are outpocketings of the thin body-wall which extend outward between the calcareous plates of the body. Surrounding the stone canal is a thin membranous tube, and within and by the side of the stone canal is a soft tubular sac. The functions of these organs are not certainly known.

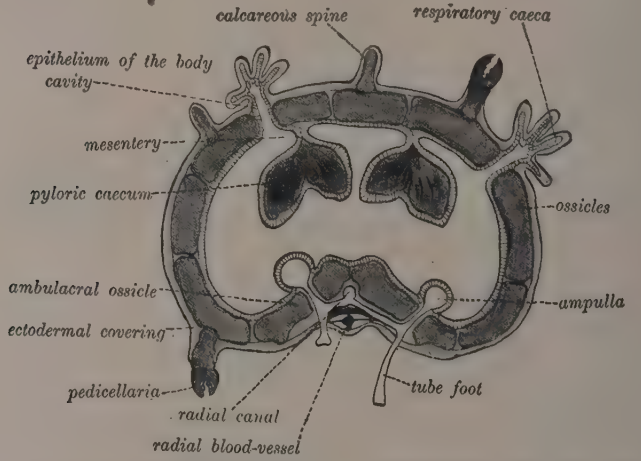


FIG. 32.—Semi-diagrammatic figure of cross-section of the ray of a starfish, *Asterias* sp.

The nervous system consists of a nerve-ring about the mouth, and nerves running from this ring beneath the radial canals along each arm.

The starfish feed upon other marine animals, especially on molluscs. They are often very destructive on oyster beds, where they may occur in such numbers as wholly to deplete the beds unless they are removed by means of rakes or tangles of ropes that are dragged over the beds for this purpose.

When the starfish wishes to feed on a mollusc that is too

large to be taken into its mouth the stomach is extended through the mouth and the living prey is covered over by it. As soon as the shell is opened ever so little the soft parts of the victim are sucked up and digested by the starfish. Having finished its meal the starfish draws its stomach in and seeks another oyster or clam.

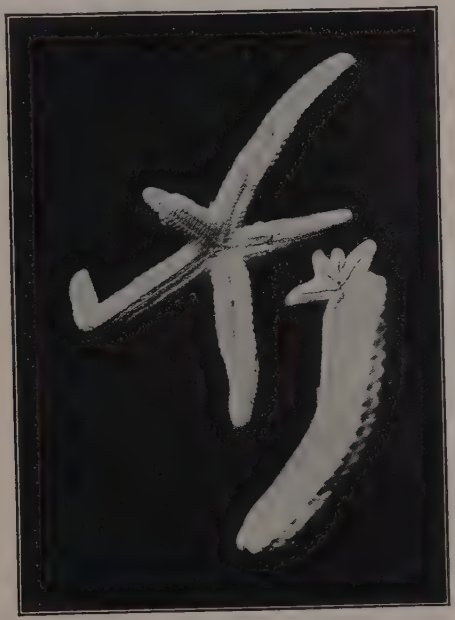


FIG. 33.—Regeneration of starfishes, *Linckia* sp. Upper figure shows a starfish regenerating arms that have been lost; the lower figure shows a portion of an arm regenerating the disk and other arms. (About natural size.)

Starfish, and in fact most of the Echinoderms, have the power of regenerating lost parts. If, through accident, a starfish loses one or more of its rays new ones will grow out to replace the old ones, or, in some cases, the arm may prac-

tically regenerate all the rest of the body. Specimens showing this process are sometimes found on the beaches. Fig. 33 shows such specimens found on the reefs in Samoa.

During its development from the egg to the adult the starfish passes through a remarkable metamorphosis. The young when it issues from the egg is more or less ellipsoidal, and is active and free-swimming, being provided with numerous cilia. This larva soon changes to another curious form with

FIG. 34.—A sea-urchin, *Strongylocentrotus franciscanus*, showing movable spines. (Reduced.)

many prominent projections. This is so unlike a starfish that the earlier naturalists did not realize that the larvæ were in any way related to the starfish and gave them the name Bipinnaria, thinking they were fully developed adult animals. The name is still used in referring to starfish larvæ, but we now know that the bipinnaria become, by later development, adult starfish.

Other Echinoderms.—All the various starfish belong to the class *Asteroidea* (Gr. *astēr*, star; *eidos*, likeness) and although they may differ much in general appearance they are all readily

recognized. Some starfish may have thirty or more rays instead of five as in the typical forms. Others may have the interradial spaces filled out nearly or quite to the tips of the rays, making the animal simply a pentagonal disk. Some are very small, less than an inch in diameter, while others attain an extent of three feet or more.

The brittle-stars belong to the class *Ophiuroidea* (Gr. *ophis*, snake; *oura*, tail; *eidos*, likeness). They differ from the

FIG. 35.—A holothurian or sea-cucumber, *Cucumaria frondosa*. (About ¼ natural size.)

Asteroidea in that the body-cavity does not extend out into the arms as it does in the starfish, or extends at most only into the bases of the arms. The five radiating rays are usually slender, more or less cylindrical, and sometimes branched.

The sea-urchins, class *Echinoidea* (Gr. *echīnos*, hedgehog; *eidos*, likeness), look quite unlike the starfish. The body is

globular, usually more or less flattened at the poles. It is covered with many movable spines which may be small and light or long and heavy. When the spines are removed the calcareous plates that constitute the firm part of the body-wall are plainly distinguished. Sea-urchins are found mostly in tide pools near the shore, but some occur at great depths.

FIG. 36.—A sea-lily, *Pentacrinus* sp. (About $\frac{1}{4}$ natural size.)

The sand-dollars, or cake-urchins, belong to the same class. Their bodies are very much flattened and often brightly colored. They are common in the sand on both the Atlantic and Pacific coasts.

The sea-cucumbers, class *Holothuroidea* (Gr. *holos*, whole; *thouros*, rushing; *eidos*, likeness), look even less like starfish.

The body is more or less cylindrical and looks not unlike a cucumber, perhaps still more like a sausage. The body-wall is tough and leathery and the five rows of tubular feet are usually, but not always, present. At one end is a ring of branched tentacles surrounding the mouth. These are often flower-like or leaf-like and brightly colored. In the Orient sea-cucumbers are largely used as food, the gathering and preparing of this trepang, as it is called, forming a very considerable industry.

Many of the feather-stars or sea-lilies, class *Crinoidea* (Gr. *krinon*, lily; *eidos*, likeness), are fixed to rocks or the sea bottom by a longer or shorter stalk which is composed of a number of segments. Others are attached by a stalk during their larval stage, but after a time the stalk is absorbed and the feather star becomes free. The central disk is provided with a number of radiating arms which are long and slender, sometimes repeatedly branched. The fine lateral *pinnulæ* on these arms give them a feather-like appearance. They occur mostly in deep water. There are comparatively few species of crinoids that still exist, but in former geologic times thousands of species flourished. The fossilized parts of their bodies, especially the little disk-like segments of the stem, are very common in Paleozoic rocks.

CHAPTER XIV

EARTHWORMS, LEECHES AND OTHER SEGMENTED WORMS

The segmented worms (branch Annelida, *annellus*, little ring), of which the earthworm is the most common example, show a decided advance in structure over the flat-worms and round-worms. Their bodies are divided into a series of segments, and most of them have well developed nervous and circulatory systems. There is a definite body-cavity, and paired organs of excretion called nephridia.

The segmented worms are grouped in four classes, the *Chætopoda* (Gr. *chaitē*, hair; *pous*, foot) including the earthworms and many marine worms; the *Hirudinea* (L. *hirudo*, leech) or leeches; and the marine *Archiannelida* (Gr. *archi-*, primitive; *annellus*, little ring) and *Gephyrea* (Gr. *gephyrā*, bridge).

The Earthworm.—In the *Chætopoda* the sides of the body are furnished with minute setæ, or with special locomotor protrusions known as parapodia. The familiar earth-worm, or angle-worm, or fish-worm, as it is often called, will serve as an example of the group. Earth-worms eat their way through the ground forming definite burrows and bringing to the surface soil from considerable depths. The earth that is swallowed as they are digging contains more or less decaying vegetable matter which is used as food. Darwin was the first to call attention to the great good that the earthworms do by opening up the soil so water can enter, enabling plant roots to penetrate deeper, and by bringing to the surface soil from which the various plant foods have not yet been taken by the plants. He estimated that in England—and conditions are practically the same in America—about ten tons of soil per acre pass annually through the bodies of these worms, and

that they cover the surface with earth at the rate of about an inch in five or six years. Besides being an important factor in increasing the fertility of the soil the earthworms furnish a considerable part of the food supply of many birds. Nor should we fail to mention the important part that they play in the welfare of mankind, or rather "boykind," when, dangling from a hook, they tempt the hungry fish from its haunts in the shade of the rocks or among the gnarled roots of the old tree. Usually they remain in the ground during the day, wandering about only at night, but sometimes, particularly after heavy rains, they may be found in considerable numbers crawling over the ground in the early morning. As they are often found on hard pavements where they have crawled or been washed by the water many persons think that they have "rained down."

External Structure.—The body of the earthworm is long, cylindrical, bluntly pointed at the anterior end and rounded and flattened at the posterior end. The four double rows of stiff bristles or setæ are hardly visible to the naked eye but they may be detected by drawing the worm backward across the hand. Over the mouth is a small lobe called the *prostomium*, and a short distance behind it is a broad thickened ring or girdle, the *clitellum*. This is a glandular structure which secretes the cases in which the eggs are laid.

Internal Structure.—If a careful incision is made along the dorsal line extending from behind the clitelleum to the anterior end of the body the sides of the body-wall may be fastened aside so as to expose the internal organs. The body-wall is made up of a thin transparent covering, the *cuticle*, just beneath which is a less transparent layer, the *epidermis*, and two layers of muscles, an outer circular layer and an inner longitudinal layer. The space between the body-wall and the alimentary canal is the body-cavity, or *cœlom*. It is divided into sections or segments by thin membranes, the *septa*. The body of the earthworm may be compared to two tubes, a larger outer one represented by the body-wall and a smaller inner one, the alimentary canal, extending from one end to the other. The space between these is the body-cavity.

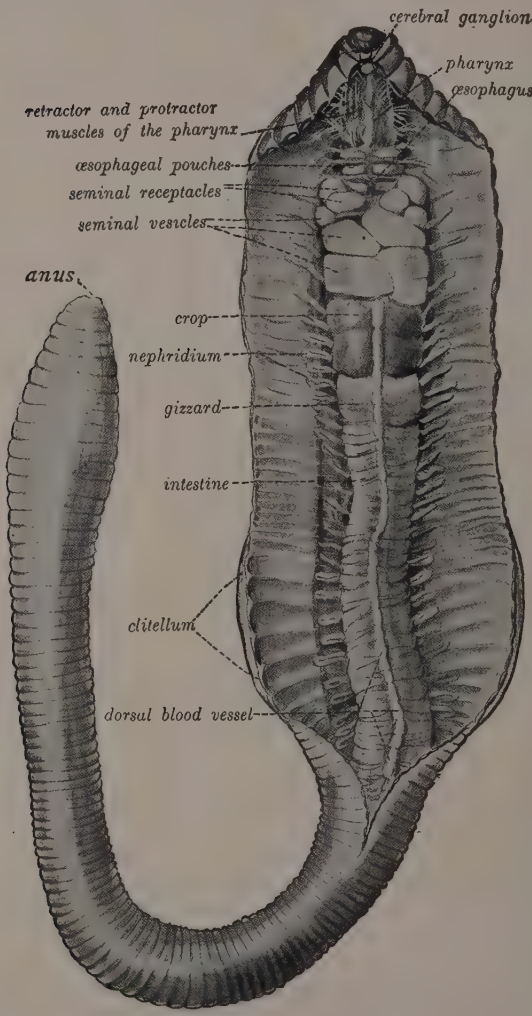


FIG. 37.—Dissection of the earthworm, *Lumbricus* sp.

This is an arrangement that we find common in all the higher animals.

In the alimentary canal a number of distinct parts may be recognized. Anteriorly is the muscular *pharynx*, which is followed by a narrow *esophagus* leading directly into the thin-walled *crop;* next comes the muscular *gizzard*, and next the *intestine*, which opens externally in the terminal segment through the *anus*. The anterior end of the alimentary canal is more or less protrusible, while the posterior portion is held more firmly in place by the septa, which act as *mesenteries*. Surrounding the narrow esophagus are the *reproductive organs*, three pairs of large white bodies and two pairs of smaller sacs. Under the reproductive organs are three pairs of bag-like structures projecting from the esophagus. The front pair are the *esophageal pouches;* the next two pairs are the *esophageal*, or *calciferous*, *glands*. They communicate with the alimentary canal, and secrete a milky calcareous fluid.

By cutting transversely through the alimentary canal in the region of the clitellum, a dorsal fold of the intestine, the *typhlosole*, may be seen extending into the lumen. This fold gives a greater surface for digestion, and in it are a great many *hepatic* or special *digestive cells*. The entire alimentary canal is lined internally with *epithelium*.

The *dorsal blood-vessel* lies along the dorsal surface of the alimentary canal. From the anterior portion there arise several *circumesophageal rings*, or "hearts." These hearts are contractile, and serve to keep the blood in motion through the blood-vessels. Just beneath the alimentary canal is the *ventral blood-vessel*, and still beneath this the *ventral nerve-cord*. The slight swellings on the nerve-cord in each segment of the body are the *ganglia*. The *brain*, or *cerebral ganglion*, lies in the first segment of the body above the esophagus, and is connected with the ventral nerve chain by the *circumesophageal collar*.

The *excretory system* is peculiar, consisting of a series of small convoluted tubes, the inner ends of which are furnished with small ciliated funnels which gather and carry off the waste matter from the fluid that fills the body-cavity. There are

no special organs of respiration, but the thin walls of the skin are traversed by a network of minute blood-vessels which are separated from the air by only a very thin membrane through which the oxygen passes readily and the carbon dioxide is given off.

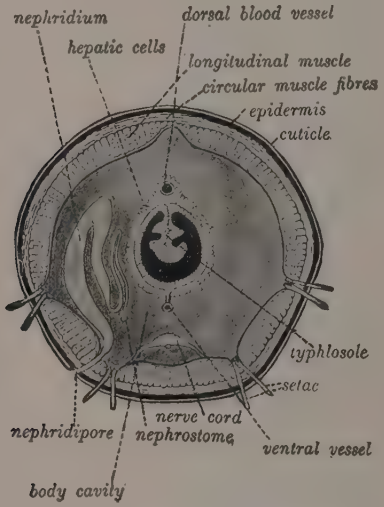


FIG. 38.—Cross-section of earthworm.

The earthworm is *hermaphroditic*, that is, both spermatozoa and ova are produced in the same individual. The *testes* are two pairs of flattened glands lying in the region of the tenth and eleventh segments. These are connected with the *seminal vesicles* and communicate with the exterior through the long *vasa deferentia* which open in the fifteenth segment. The *ovaries* are attached to the septa separating the twelfth and thirteenth segments. The ova reach the exterior through a pair of funnel-shaped *oviducts*, the mouths of which are near the ovaries.

They pass through the septum between the thirteenth and fourteenth segments and open through the ventral wall of the fourteenth segment. The sperm cells do not fertilize the ova from the same individual. When the reproductive elements are ripe, two worms mate and there is a transference of spermatozoa from each individual to the other. The clitellum then becomes very much swollen, and finally forms a collar-like structure about the body of the worm. As this slips forward the ova are discharged into it, and a little further forward the sperm cells that have been received during copulation are also emptied into it. As it passes on over the

FIG. 39.—A group of marine worms. At the left a gephyrean, *Dendrostomum cronjhelmi*, the upper right-hand one a nereid, *Nereis* sp., the lower right-hand one, *Polynœ brevisetosa*. (From living specimens in a tide-pool in the Bay of Monterey, California.)

head both ends of the collar become sealed and thus a capsule containing the ova and spermatozoa is formed. This capsule lies in the ground until the young are hatched. Only a part of the eggs in each capsule develop, the rest being used for food by the growing young.

The Marine Worms.—To the genus *Nereis* belong many of the large marine worms that are found on almost all sea beaches. The head is provided with two pairs of eyes and with several tentacles which act as feelers. The sides of the

body are provided with lateral plates, a pair to each segment. These plates are divided into lobes, and aid the animal in crawling or swimming, and as some of them are well provided with blood-vessels they also serve as respiratory organs.

Many of the marine worms swim in the sea, others are more or less closely confined to their burrows, while some form tubes of sand or gravel or secrete tubes of lime which furnish excellent protection. Such tube-like houses are often found on rocks and shells. They may usually be found on the oyster shells in almost any market. The part of the body that is protected has no further use for the lateral appendages and so they have almost or quite disappeared. On the head, however, there have been developed great plume-like appendages which are well supplied with blood-vessels and act as gills. These organs are often beautifully colored, and when fully expanded look like gorgeous flowers. Indeed, these worms and the sea-anemones make veritable flower gardens in many a tide pool along rocky shores.

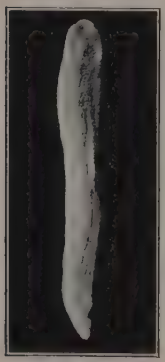


FIG. 40. The medicinal leech, *Hirudo medicinalis*. (Grows to be six or eight inches long.)

The Leeches.—In their general appearance the leeches look much more like the flatworms (Platyhelminthes), than like the other Annelida. The body is flattened, and composed of many segments. Most of the segments are marked by transverse lines, making the animal appear to have many more segments than it really has. The ventral side is provided with two sucking disks. The mouth, which lies in the anterior disk, is provided with sharp jaws which enable the leech to puncture the skin of animals in order that it may suck their blood. Leeches live mostly in the water, and are found most commonly on such animals as fish, frogs and others that are aquatic or semi-aquatic. They will readily attack man when the opportunity offers, and in olden days they were much used by physicians to "bleed" their patients. A leech was allowed to at-

tach itself to the body of a patient and feed until it was completely gorged. Leech farms where these "medicinal leeches" were raised were formerly common in some countries, and a jar of live leeches was a part of the regular stock of the apothecary. They are now seldom used.

CHAPTER XV

CRAYFISH, LOBSTERS, CRABS, SHRIMPS, ETC.

The great branch Arthropoda (Gr. *arthron*, joint; *pous*, foot) comprises, as shown by the table of classification on pages 55 to 57, five classes; the *Crustacea* (L. *crusta*, crust), or crayfishes, crabs, lobsters, barnacles, etc.; the *Onychophora* (Gr. *onyx*, claw; *phero*, bear) or slime slugs; the *Myriapoda* (Gr. *myrios*, numberless; *pous*, foot) or centipedes and thousand-legged worms; the *Arachnida* (Gr. *arachne*, spider) or scorpions, spiders, mites and ticks; and the *Insecta* (L. *insectum*, cut into), which in point of number of species, is by far the largest class in the whole animal kingdom.

The Arthropods get their name from two Greek words meaning jointed foot, and the members of the branch are characterized by the possession of legs and other laterally arranged paired appendages each composed of several successive jointed parts. The bodies of all Arthropods are bilaterally symmetrical, and are composed, as are those of the Annelida, or annulate worms, of a series of successive segments. They are inclosed by a more or less firm outer cuticle, which not only serves as a protection to the soft body parts within but also provides firm points of attachment for the muscles. This hardened cuticle is called the exoskeleton.

The internal organs of the Arthropods show a more or less obvious segmentation corresponding with the segmentation of the body wall. The alimentary canal runs longitudinally through the center of the body from mouth to anal opening. The nervous system consists of a brain lying above the esophagus and a double nerve-chain running backward from the esophagus, along the median line of the ventral wall, to the posterior extremity of the body. This ventral nerve-chain consists of a pair of longitudinal cords and a series of pairs of

ganglia, arranged segmentally. The two ganglia of each pair are fused more or less nearly completely to form a single ganglion, and the nerve-cords are partially fused, or at least lie close together. In addition there is a smaller sympathetic system composed of a few small ganglia and certain nerves running from them to the viscera, this system being connected with the main or central nervous system. In this group the organs of special sense reach for the first time a high stage of development. Compound eyes are peculiar to Arthropoda. The heart lies above the alimentary canal. Respiration is carried on by gills, in the aquatic forms, and by a remarkable system of air-tubes or tracheæ in the land forms (insects). The sexes are usually distinct, and reproduction is almost universally sexual. Most of the species lay eggs.

Crustaceans

The members of the large and important class *Crustacea* are mostly aquatic, but a few species are found on land in moist places. There are over ten thousand known species in the class, about nine-tenths of which are marine.

Many are scavengers, feeding on any dead organic matter, and thus doing a great service in helping to keep the shores, small pools, and even the sea clean. Some prefer a vegetarian diet and may do much damage to wood that is in the water or even to crops on the land. The lobsters, crayfishes, crabs, shrimps and prawns furnish man with an abundant supply of most dainty food, and more important still, they furnish an almost inexhaustible supply of food to many other aquatic animals.

The name *Crustacea* refers to the covering or crust (exoskeleton) that protects the softer parts of the body and serves for the attachment of the muscles. This crust may be very hard, as with the crabs, or soft and delicate, as with some of the smaller forms.

The Crayfish.—The crayfish will serve as a typical example of the class, but the group contains many remarkable and important deviations from the type. The body is divided into two well defined regions, the *cephalothorax* and the *ab-*

domen. The cephalothorax is covered above and on the sides by the firm *carapace*, which is divided by the transverse *cervical suture* into parts corresponding to the head and thorax. The *compound eyes* are situated at the ends of two short stalks which arise just beneath the *rostrum*, the anterior horn-like projection of the carapace. The segments of which the cephalothorax is composed are so fused together that they are not readily distinguished, but each segment of the body bears a pair of appendages and by the position and character of these appendages the different regions can be determined. Each of these appendages, except the antennæ, consists of a basal part from which arises two branches made up of one or more segments modified to perform certain functions.

Just below the eyes is the first pair of appendages, the *antennules*, in the base of each of which is an organ formerly supposed to be an auditory organ but now known to be an organ of equilibration. These aid the animal in keeping the body in a proper position while swimming. Next come the *antennæ*, or feelers, which, like the antennules, are provided with fine hairs which aid in the sense of touch and perhaps of smell. The *green gland* lies at the base of the antennæ. It is probably an excretory organ with functions similar to the kidneys of higher animals.

Next comes the group of appendages surrounding the mouth, the *mandibles*, two pairs of *maxillæ* and three pairs of *maxillipeds*. The mandibles are hard and jaw-like. The second maxillæ have a large paddle-like structure, the *scaphognathite*, which extends back over the gills in the *branchial chamber*, the space between the lower part of the carapace and the body-wall. The movements of this appendage keep the currents of water flowing through the gill chamber. The maxillipeds are appendages of the thorax. The first pair of legs is much larger than the others, the terminal segments being developed into strong pincers or *chelæ*. Each pair of legs, except the last, bears gills which extend up into the branchial chamber. In the basal segments of the last pair of legs of the male are the *genital pores*. In the female the genital pores are in the basal segments of the second pair of walking-legs. In the

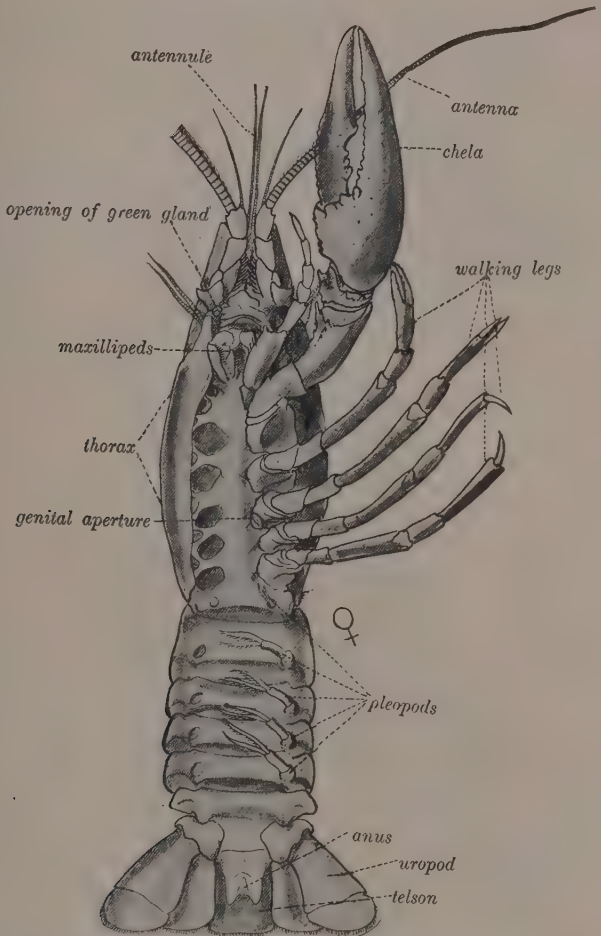


FIG. 41.—Ventral aspect of female crayfish, *Cambarus* sp., with the appendages of one side removed.

male each segment of the abdomen, except the last, bears a pair of appendages or *swimmerets*. The first two pairs are modified to serve as channels for the sperm fluid. The last pair of appendages is broad and flat and with the last segment, the *telson*, forms the broad tail, or swimming fin. In the female the first two pairs of abdominal appendages are very small or altogether lacking.

The food, which for the most part consists of vegetable matter, or dead organic matter, passes into the *stomach* through a short *esophagus*. The stomach is divided into two parts. The anterior portion, the *cardiac chamber*, contains three strong teeth, the *gastric mill*. These grind the food before it passes back through a fine strainer of stiff hairs into the second or *pyloric chamber*, which receives the secretions from the large *digestive glands* that surround the stomach. The intestine is a straight tube opening to the outside by a slit-like anal opening on the under side of the telson.

The *heart* lies in the *pericardial sinus* in the posterior portion of the cephalothorax. The contractions of the heart force the blood out into seven arteries which carry it to all parts of the body. The *ophthalmic artery* supplies the eyes and other parts of the head. The two *antennary arteries* supply the antennæ, excretory organs and other tissues. The two *hepatic arteries* supply the digestive glands. The dorsal *abdominal artery* supplies the intestine and surrounding tissues. The *sternal artery* passes down to the ventral wall where it divides, one part carrying blood to the appendages in the thorax and the other part to the appendages of the abdomen. All of the arteries give off many branches which divide again and again into very small *capillaries* which open into spaces between the tissues. From all of the tissues the blood finally makes its way to a large space, the *sternal sinus*, in the ventral part of the thorax. From the sinus it passes out into channels in the gills where it gives off its carbon dioxide and receives oxygen from the water which bathes the gills. Then through other channels, the *branchio-cardiac sinuses*, it reaches the pericardial sinus which surrounds the heart. From here it enters the heart through three pairs of openings,

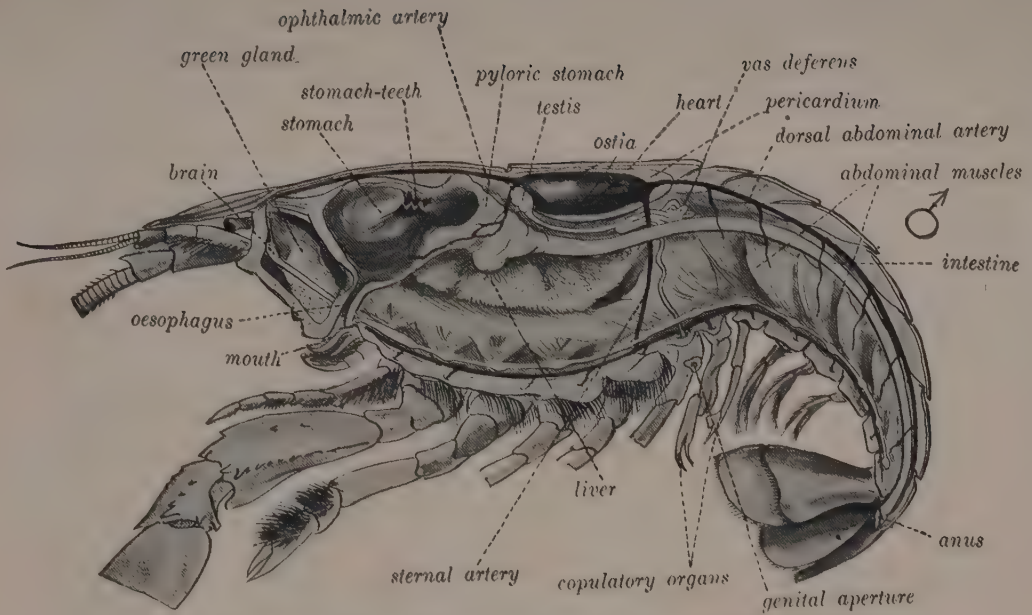


FIG. 42.—Diagrammatic median longitudinal section of male crayfish, *Cambarus* sp.

the *ostia*, which are guarded by valves that allow the blood to enter but prevent it from flowing back into the sinus.

The nervous system is similar to that of the earthworm and the insects. It consists of a dorsal ganglionic mass, the *brain*, which is connected by cords passing around the esophagus with the *ventral nerve cord* which lies along the floor of the thorax and abdomen. Along the ventral nerve cord are a number of *ganglia* which give off nerve fibers that reach the various parts of the body.

The abdomen is quite filled with the powerful muscles that flex that part of the body forward when the crayfish is swimming, thus producing backward locomotion. These muscles, as well as the strong muscles of the appendages, are all attached to the firm body-wall, or exoskeleton, not to an internal skeleton as in the vertebrates.

The sexes are separated. The *spermatozoa* are produced in the male in the tri-lobed *testis* which lies under the heart and over the anterior end of the intestine. They pass through the long, coiled, paired *vasa deferentia* to the genital apertures in the base of the last pair of thoracic legs. The *eggs* arise in the bilobed *ovary* in the female and pass through the paired *oviducts* and out through the genital apertures on the second pair of thoracic legs. The eggs are glued to the swimmerets of the female, and remain in this position until they hatch.

During the very early part of their development the young or larval crayfish cling to the old egg shells or to the spinnerets of their mother thus receiving much needed protection, for their bodies are very soft. After about two days the young make their first moult, casting off the old skin after a new one has been formed underneath it. They usually moult about seven times during the first summer and grow very rapidly after each moult. In the process of moulting the lining of the esophagus, stomach and the alimentary canal is also cast off. Often one or more of the appendages may be lost during moulting. Such lost parts are usually regenerated and it is not uncommon to find individuals with one of the claws or legs shorter than the others, the short appendage being a new one that is replacing one that has been lost.

Crayfish, or crawfish, as they are more commonly called, are found in most fresh water ponds and streams. The common species in the eastern United States belong to the genus *Cambarus*, those on the Pacific Coast to the genus *Astacus*. Some species live in holes in the ground, digging deep enough to reach water, or at least considerable moisture. The earth that is removed in digging the burrows is sometimes built up to form short chimneys above the ground. This burrowing habit is often the cause of serious damage to the levees along the rivers, particularly along the Mississippi River. In the southern United States crayfish often occur in such numbers that they become important pests in the corn and cotton fields. In badly infested areas there may be as many as 10,000 or 12,000 holes to the acre. From these holes the crayfish issue in the evenings or on rainy mornings and feed on the young tender plants. They may be easily killed by placing a little carbon bisulphid in each hole.

In some sections of the country crayfish are used for food and are considered a great delicacy, those on the west coast, on account of their size, being particularly in demand. Recent attempts have been made to introduce these larger species into waters where only the smaller ones occur naturally. In Europe the crayfish have been used for food for centuries and in France "crayfish farming" has been successfully practiced for many years.

Classification

The class *Crustacea* is divided into two sub-classes, the *Entomostraca* and the *Malacostraca*.

Sub-class Entomostraca.—*Entomostraca* are mostly small, comparatively simple forms with little differentiation of the appendages. Four orders are included in this class. The order *Phyllopoda* comprises mostly fresh water species with leaf-like appendages. The "fairy shrimps," common in fresh water pools in the early spring, are among the largest examples. The species of *Artemia*, an abundant Phyllopod in salt and brackish or fresh water, are of great interest to biologists on account

of the changes that may take place in them when the density of the water is changed. *Artemia* and several other genera belonging to this order form a very important food supply for many fishes.

To the order *Ostracoda* belong several genera; *Cypris*, which occurs in fresh water, and *Cypridina*, which is marine, are the most common. These resemble minute bivalve shells and often occur in great numbers near the surface where the surface-haunting fish and other animals feed on them.

FIG. 43.—Water-flea, *Cyclops*, female with egg masses. (From life, greatly magnified.)

In the order *Copepoda* the body is long and distinctly segmented, and the appendages are confined to the head and thorax. The water-fleas, *Cyclops*, are common in all pools or quiet waters. The single median eye has suggested the generic name. These are often used as examples to show how rapidly some of these forms may multiply. It has been estimated that the descendants of a single individual might in one year number nearly 4,500,000,000, if all the young lived and produced their full number of offspring. They feed on other smaller animals such as Protozoa and Rotifera, and in turn serve as one of the most important sources of food for the young of many fresh water fishes. Related to Cyclops is the genus *Cetochilus* which occurs in the surface water of the sea in inconceivable numbers, sometimes forming almost a solid mass extending for miles in quiet waters. Those whales which are furnished with fringes of whalebone in the mouth often swim in schools through the water where these minute creatures abound, and as the water rushes through the wide-open mouth the minute crustaceans are strained out and thus furnish a dainty and abundant supply of food for the largest of living animals. To the genus *Sapphirina* belong some of the most wonderfully phosphorescent animals that are found in the sea. This order also includes the so-called

fish-lice which are especially interesting because of their parasitic habits and the greatly modified structure resulting therefrom. Some live as commensals, that is, are associated with their hosts in such a way as to derive benefit from them, without injuring them. Others are truly parasitic and live upon the blood or tissues of their host. The most common of these attach themselves to the gills of fishes, but they may also be found as external or internal parasites, of whales, molluscs, marine worms, starfishes and many other animals that are found in the sea.

The barnacles, order *Cirripedia*, look but little like other Crustacea. For a long while they were classed with the Molluscs, but a study of their development showed that in the young stages they are like the crustaceans and not the molluscs. The young are free-swimming, and after going through a series of changes they become attached to some firm object. Here the young barnacle undergoes further metamorphosis, and the adult form with its compact or somewhat worm-like body is developed. The appendages, or legs, are long, slender and curled. The animal is enclosed in a shell often of the shape of a truncate cone and composed of six or more plates. The open end of the shell may be closed by a lid or operculum, thus well protecting the inmate. The barnacle feeds on minute organisms which it sweeps into its mouth by means of the long feathery appendages.

FIG. 44.—A stalked barnacle, *Lepas hillii*. (About ½ natural size.)

Although barnacles may completely cover piling and other timbers in the water, they do not injure them and may even be of some service in protecting them from wood-boring or wood-destroying animals. Sometimes, however, they are serious pests on oyster beds. The goose-barnacle, or ship-

barnacle, is attached to floating objects by means of a flexible stalk which may be very short or may attain a length of nearly a foot. In warm seas the bottoms of ships are often so covered with these barnacles that their progress is seriously impeded.

The very degenerate parasitic *Sacculina* also belongs to this order. The young sacculina swims about freely, but soon attaches itself to the body of a crab. After undergoing a series of changes, one stage of which is passed within the body of the crab, it finally becomes little more than an ovoid sack closely applied to the host, and sending off many root-like filaments which extend to all of the tissues of the crab from which it derives its nourishment.

Sub-class Malacostraca.—This group includes the more highly organized Crustacea. Most of them are of considerable size, and the appendages show much differentiation. There are several orders, some including mostly fresh water, others mostly marine forms, but the members of only two of these orders are of any particular economic interest or importance except as they furnish food for fishes and other smaller animals.

The order *Decapoda*, to which the crayfish belongs, is the largest and most important order belonging to the class. The order is divided into two groups, or sub-orders, the *Macrura* and the *Brachyura*. In the *Brachyura* the abdomen is usually much reduced in size and folded underneath the thorax. The *Macrura* includes the free-swimming shrimps and prawns, the crawling lobsters and crayfish, and the hermit crabs, sand bugs and others.

Lobsters.—As a source of food for man the lobsters rank first among the Crustaceans. They are found along rocky shores on both sides of the Atlantic ocean. In structure and habits they are much like the crayfish, but they attain a much greater size, some individuals reaching a length of twenty inches and a weight of twenty-five pounds. At rare intervals even larger specimens are found, but these are to be regarded as giants. The lobsters seen in the market usually measure ten to twelve inches and weigh from one and one-half to two and one-half pounds. Many states do not allow lobsters to be

taken that are less than nine inches long; others place the minimum at ten or ten and one-half inches.

The food of lobsters consists of fish and any other animals that they can capture in the sea. Although they prefer fresh food they do not hesitate to eat dead or even decomposing animal matter.

Females eight or ten inches long may produce 5000 to 10,000 eggs. Very large lobsters may produce nearly ten times this number. The eggs are glued to the swimmerets and thus protected as are the eggs of the crayfish.

Live lobsters are brownish or greenish with bluish mottlings. The ones usually seen in the market are red because they have been boiled.

At one time lobsters were very plentiful and very cheap along the New England and Canadian coasts. It was no uncommon thing for as many as 100,000,000 to be marketed in a year, and the price was often as low as five cents for a large lobster. But for the last thirty years the numbers have been decreasing very rapidly until now the catch is only a small fraction of what it used to be, possibly little more than one-tenth, and many of the best grounds are no longer fished because they do not yield profitable returns. As the supply decreased the prices rapidly increased until now in many places lobsters sell from fifty cents to one dollar each. The problem of how to conserve the supply that still exists is a very important one and has been the subject of much study and experimenting. Closed seasons and a gauge or length limit have been tried. "Egg-lobster" laws have been passed for the protection of the female during the time she is carrying her eggs. But there has been only a partial check in the destruction of the industry. With certain modifications of these laws and with the methods of artificial propagation that are now being practiced in some states, it is hoped that more encouraging results may be met with. The lobster fisheries on the seacoasts of Europe have had the same difficulties that have been met with here.

The common American lobster is called *Homarus americanus*, and the common lobster of Europe *H. grammarus*, the Nor-

wegian lobster, *Nephrops norwegicus*. Around the islands off the coast of California is a large crustacean about the size of the eastern lobster, but the front legs are not enlarged into the great heavy pincers. It is often referred to as the spiny lobster, or "salt water crawfish." It belongs to the genus *Palinurus*, which is represented in different parts of the world by several species that are highly valued as food.

Shrimps and Prawns.—The prawns, which are marine and much like the lobsters but very much smaller, and the shrimps, which occur in both fresh and salt water, are often much sought after for food. They often occur in great "schools," and are caught in nets or dredges, sometimes in great numbers. They are put fresh directly on the market, or are canned and shipped to all parts of the world. The principal shrimp fisheries are along the shores of the Gulf of Mexico where the common shrimp, *Crangon vulgaris*, is exceedingly abundant. Most of the canned shrimp come from this region. The same species occurs on the Pacific coast where, however, the California shrimp, *C. franciscorum*, is more important. Besides supplying the local markets with the fresh shrimp the California Chinese formerly dried great quantities of them. The dried meat was separated from the shell and exported, the value of the export reaching $100,000, in some seasons.

Some of the largest and finest prawns and shrimps are found in Puget Sound, but the demand for them is so great that they seldom get beyond the local market. Like the lobster fisheries, the shrimp fisheries have suffered from lack of intelligent regulation.

It should be noted that these crustaceans, which occur in untold numbers in so many waters, form a large part of the food supply of many of our important food fishes, and the destruction or material reduction of this source of food has an effect more far-reaching than at first appears.

The hermit crabs, which are more nearly related to the shrimps and prawns than to the true crabs, found along all seashores, well illustrate the structural changes that may be brought about by a special or peculiar mode of life. Very early the young animals seek out an empty shell, such as a snail or

periwinkle shell, in which they may hide. The body is thrust well into the shell and the opening guarded by the feet and claws. As the crab develops it becomes more and more adapted to the shell in which it is living. The abdomen remains soft and follows the convolutions of the shell. Only the last two abdominal appendages remain, and these are modified into hook-like organs. The first two or three pairs of thoracic legs

FIG. 45.—A hermit crab, *Pagarus* sp. in a sea-snail shell. Upper figure shows another crab removed from its shell. (Reduced.)

become curiously modified and help close the opening of the shell. The right claw is often very much larger than the left and well fitted for the dual purpose of capturing prey and acting as a door. As the crab grows, its adopted home becomes too small for it, and from time to time it must seek larger shells.

Some of the hermit crabs always have certain stinging

hydroids or sea-anemones attached to their shells. Both animals doubtless derive some benefit from this association, the crab being protected from its enemies and the hydroid or anemone being moved from place to place where food is more abundant and perhaps gathering some of the bits that are scattered in the water when the crab is feeding. This is another example of commensalism, or symbiosis.

The sand-bugs, genus *Hippa*, so numerous on sandy beaches, burrowing rapidly into the loose sands or sometimes swimming about in the tide pools, are an important source of food for some fish.

Many other interesting forms in this sub-order, some of them of more or less economic importance, might be listed, but the kinds already mentioned serve to show something of the diversity of structure and habits of the group.

Crabs.—The true crabs, belonging to the sub-order *Brachyura*, differ from the crayfish and lobsters in having the body short and broad instead of elongate and rounded. The cephalothorax is often broader than long. The abdomen is relatively small and is bent under the cephalothorax so that but little of it is visible from above. The appendages are usually well developed and similar to those of the crayfish or lobster except that the number of abdominal appendages is reduced to two pairs in the male and four pairs in the female. Most crabs are scavengers, living on dead animal matter. During their development they undergo a remarkable metamorphosis. In some of these stages they are so unlike the adult that they were described as different animals. The names, such as *zoea* and *megalops*, given to these supposedly distinct animals, are still retained, but we know now that they refer to different stages in the development of the crab.

Most of the crabs live in the shallow waters near the shore, but some live in deep water and a few live on land. Their habits are various and there is a corresponding variation in their structure and shape, size and coloring.

The spider crabs, with their long, slender legs and comparatively small body, are especially strange looking creatures. Some members of this group living in Japanese waters measure

twelve to sixteen feet across the extended legs, the body itself being but little more than a foot in width or length.

The fiddler crabs, *Uca* spp., so common along the Atlantic coast, are the clowns among the crabs. The males have one of the chelæ very much enlarged, and when alarmed they move this swiftly back and forth with a motion ridiculously like that of a violinist with his bow.

The blue crab, or "soft-shelled" crab, *Callinectes hastatus*, is the most important as a source of food on the Atlantic coast. On the Pacific Coast a much larger crab, *Cancer magister*, is taken in shallow waters, sometimes in considerable numbers, and is much prized.

The horseshoe crab, or king-crab, *Limulus*, common all along the Atlantic coast, is really not a crab at all, nor even a crustacean, but belongs to another class, the relationship which is uncertain. Many believe that Limulus is most nearly related to the spiders.

The beach fleas, order *Amphipoda*, are perhaps the most numerous crustaceans found on the sea beaches, occurring in countless numbers in the tossed up seaweeds and mosses and other sea wrack. They are important as food for other marine animals. The boring Amphipod, genus *Chelura*, works on submerged timber, often doing a great deal of damage.

FIG. 46.—A sow-bug, *Isopod*, species not determined.

The wood-lice or sow-bugs, order *Isopoda*, are among the few crustaceans that live a wholly terrestrial life. They live in moist places, feeding chiefly on decaying vegetable matter, but sometimes attacking tender plants and doing more or less damage in gardens and green-houses. Although land animals, they breathe by means of gills which are situated on the under side of the abdomen. It is therefore necessary for them to live in places where the gills may be kept damp in order that there may be a ready transfer of gases through the membranes.

Their breeding or hiding places are usually easily found and destroyed, or sliced potatoes or substances poisoned with Paris green may be placed where the sow-bugs can find them. Some members of this same order live in fresh water, others are marine.

The gribbles, genus *Limnoria*, are another group of crustaceans that are very destructive to piles and other submerged woods, which they may completely honeycomb to the depth of half an inch or more. Where abundant they may cause the piles to lose as much as an inch of surface each year. It is a common practice now to give the piles a coat of creosote, or better still to drive the creosote into the wood by pressure, in order to protect it from the ravages of these and other wood boring species. These gribbles attack and destroy much floating and water-logged timber that might otherwise become serious obstructions to navigation.

CHAPTER XVI

SLIME SLUGS, MYRIAPODS AND INSECTS

Slime Slugs.—The slime slugs, composing the small class Onychophora of the great branch Arthropoda, are curious, soft-bodied, many-legged, but sluggish creatures about two inches long, that live under bark or stones mostly in sub-tropic and tropic lands. About fifty species of them are known. The best known genus is named *Peripatus*. They capture small insects for food by ejecting slime on them from glands in the mouth. Their bodies show a curious combination of worm character and arthropod characters. The animals really seem to be a sort of link between the Annelida and the Arthropoda.

FIG. 47.—*Peripatus eiseni* (Mexico). (Length about two inches.)

Myriapods.—The class Myriapoda[1] includes the familiar thousand-legged or galley worms and centipedes as well as certain smaller creatures bearing only a few pairs of legs. They are land animals, and have the body segments nearly uniform in size and shape, except the head which bears the mouth-parts and antennæ. The presence of true legs on most of the segments of the hinder part of the body and the lack of the grouping of these segments into distinct thorax and abdomen are the further external structural characteristics which distinguish myriapods from insects. The internal anatomy corresponds in general character with that of the Insecta.

[1] Modern classification tends to discard the long recognized class Myriapoda in favor of two classes, one for the centipedes and allies, and the other for the thousand-legged worms and allies.

The most familiar myriapods are the millipeds or galley worms, the centipedes, geophilids, and lithobians. The millipeds are cylindrical in shape, have two pairs of legs on most of the body-segments and are vegetable feeders, though some may feed on dead animal matter. The galley-worms, *Julus* spp., large, blackish, cylindrical millipeds found under stones and logs and leaves in loose soil, are familiar forms. They crawl slowly, and when disturbed curl up and emit a malodorous fluid. They can easily be kept alive in shallow glass vessels with a layer of earth in the bottom, and their habits

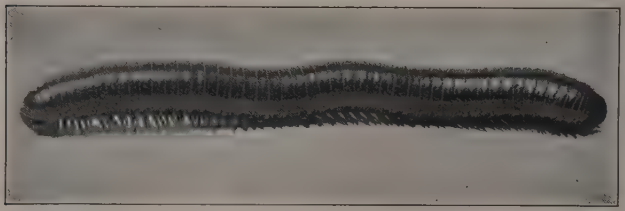


FIG. 48.—A milliped, *Julus* sp. (Natural size.)

and life history may thus be studied. They should be fed sliced apples, green leaves, grass, strawberries, fresh ears of corn, etc. They are not poisonous and may be handled with impunity. They lay their eggs in little spherical cells or nests in the ground. An English species, of which the life history has been studied, lays from 60 to 100 eggs at a time. The eggs of this species hatch in about 12 days.

The lithobians, centipedes and geophilids are flattened and have but a single pair of legs on each body-ring. They are predaceous in habit, catching and killing insects, snails, earthworms, etc. They can run rapidly, and have the first pair of legs modified into a pair of poison claws, which are bent forward so as to lie near the mouth. The common "skein" centipede, *Scutigera forceps*, is yellowish and has fifteen pairs of legs, long 40-segmented antennæ, and nine large and six smaller dorsal segmental plates. The true centipedes, *Scolo-*

pendra spp., have twenty-one to twenty-three body-rings, each with a pair of legs, and the antennæ have seventeen to twenty joints. They live in warm regions, some growing to be as long as twelve inches or more. The "bite" or wound made by the poison claws is fatal to insects and other small animals, their prey, and painful or even dangerous to man. The popular notion that a centipede "stings" with all of its feet is fallacious. It is recorded by Humboldt that centipedes are eaten by some of the South American Indians. The geophilids are very slender-bodied and usually rather long centipede-like forms with as many as 300 pairs of legs. They are usually yellowish and are common in damp places under stones or logs, or in the ground.

FIG. 49.—A centipede, *Scolopendra* sp. (Natural size.)

Insects

The great class Insecta, with its 350,000 known species, is a group of animals of special importance in the study of economic zoology. As we know but few more than 500,000 different kinds of animals altogether, it is apparent how dominant among animals, as regards numbers at least, the insects are. In fact we might well call this the Age of Man and Insects, to contrast it with the earlier Age of Reptiles, Age of Fishes, Age of Invertebrates, etc. The insects include more kinds of animals directly injurious to the material welfare of man and to his health and duration of life than any other animal group. So it is that as students of economic zoology we must give insects, and their relations to man, a more detailed consideration than we shall give any other animals.

Although from the silk-worm we get all the silken cloth and thread we use, and from the honey-bee all the honey and beeswax, yet these are almost the only species of insects of all the myriad living kinds that afford man useful products. But in two other and far more important ways, insects are of direct benefit to us. Some of them act as scavengers of considerable importance, and many of them kill injurious species of their own class. It is, indeed, on the many predaceous and parasitic insects that we rely for chief protection from the many injurious and dangerous kinds. We can, and do, make much headway against injurious insects by the use of artificial remedies, but without natural checks on their increase, among which checks the attacks of other insect species are the most important, insect pests would overrun us completely.

A knowledge of the special structure, physiology and mode of development of insects is necessary as a basis for good work in economic or applied entomology. And a knowledge of insect classification, which of course is based on similarities and dissimilarities both of structure and of development and habit, and which indicates by a few words the existence of these resemblances and differences, is also most important to the economic entomologist. Hence our first consideration of insects will concern itself with their structure, physiology, development and classification. The study of the grasshopper, already made, has given us a good understanding of the insect body. But there is much modification, or specialization, of general body-shape and character as well as of the various particular parts of it, as antennæ, mouth-parts, legs, wings, etc., and it will be advisable to examine in some detail the external features of the body of a highly specialized insect such as the honey-bee. A number of statements concerning the general make-up of the insect body, already made in connection with the study of the grasshopper, will be repeated and expanded and a number of technical names of parts of the body redefined. The grasshopper was studied primarily as an introduction to the invertebrates in general. The bee will be studied primarily as an introduction to the insects.

The External Structure of the Honey-bee

Body-wall.—The body of a bee, which is a well-developed insect type, is, let us note first of all, entirely covered by a firm body wall or hardened skin. This body-wall is composed of two layers, an inner, very thin and soft, cellular layer, the cells being arranged side by side to form a skin membrane, only one layer of cells in thickness, and an outer, thicker, non-cellular cuticular layer, composed of material secreted by the skin cells and perhaps partly of the hardened outer ends of these cells themselves. This thick, firm, colored cuticle is made up of

Fig. 50.—Honey-bee, *Apis mellifica*. (Nearly 3 times natural size.)

successive fine laminæ well fused together, and is composed chiefly of a complex sustance called *chitin*. It is this chitinized cuticle which gives the body-wall of insects its hardness, and makes of it not only a firm protecting cover for the soft parts within but also an exoskeleton to which the muscles are attached. The chitinized cuticle, although extending continuously over the body, is flexible in certain places, as between the head and thorax, thorax and abdomen, various abdominal segments and at the articulations of antennæ, mouth-parts, legs, wings and between the various antennal, mouth-part and leg joints, etc. This is necessary, of course, for the effective movement of all these parts. Such flexible places in the cuticle are called *sutures*, while the firmer, fixed parts are called *sclerites*.

Body-regions and Segments.—The body of a honey-bee, like that of a grasshopper, is made up of three readily distinguishable main parts or regions, the head, thorax and abdomen, each part bearing its special appendages, as antennæ and mouth-parts on the head, legs and wings on the thorax, and the parts forming the sting on the abdomen.

Each of the main body-regions is composed of several body segments, but in the head and thorax these segments are so fused as to be hardly distinguishable as separate parts. In the abdomen, however, six distinct segments can be distinguished.

All insects have the body fundamentally composed of successive segments grouped more or less compactly into three body regions. The typical number of segments fused to form the head is probably six, perhaps only four. The thorax is composed of three, called prothoracic, mesothoracic, and metathoracic. segments, while the abdomen comprises from seven to eleven segments, although in some insects these may be so fused as to make the abdomen seem made up of but three or four, or even a single segment.

Segmented Appendages.—The antennæ or "feelers" of the head, the legs, and less plainly the mouth-parts, show that each of these movable appendages of the body is made up also of a series of successive segments or "joints." The hardened body wall, the segmentation of the body, and the segmentation or jointing of the body appendages, of the bee and all other insects, are the fundamental characteristics that show their relationship to the crustaceans, myriapods, spiders and other Arthropoda.

Mouth-parts.—The mouth-parts of the bee are composed of a skin flap called upper lip or *labrum*, a pair of firm, trowel-like little jaws or *mandibles* used chiefly for moulding the wax when the cells are being built, and a complex tongue-like organ composed of various parts as shown and named in Fig. 51. This "tongue" is the nectar-gathering organ, and is so arranged that its various parts can be held together so as to form an imperfect tube inside of which a long hairy rod moves back and forth. The flower-nectar taken up on the expanded tip of this

hairy rod is forced up the tube by the pressing together of the parts composing its walls.

Antennæ and Senses.—The two feelers, or antennæ, of the bee are slender, elbowed processes, each composed of thirteen small segments, which can be moved freely, and extend out in front of the face so as to be in advance of the head when the bee is flying or walking. They are general organs of touch and smell and probably also of hearing. Each of these senses has its own particular specific organs on the antennæ, those of feeling being fine tactile hairs and papillæ, those of smell being variously shaped very minute pits or cones, each with a fine nerve ending in it, while those of hearing are more problematical. But it has been proved that many insects have special auditory organs in the antennæ consisting usually of fine hairs which can be set into vibration by the sound waves, and an elaborate receiving arrangement, in the second segment, of chitin rods, delicate nerve fibers, special ganglion cells and an auditory nerve running to the brain. The male mosquito has a very highly developed auditory apparatus of this type.

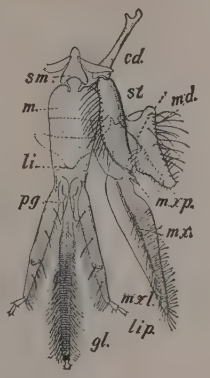


FIG. 51.—Mouth-parts of a honey-bee with maxilla and mandible of one side removed. *md.*, mandible; *mx.*, maxilla; *mx.p.*, maxillary palpus; *mx.l.*, maxillary lobe; *st.*, stipes of maxilla; *cd.*, cardo of maxilla; *li.*, labium; *sm.*, submentum of labium; *m.*, mentum of labium; *pg.*, paraglossa. *gl.*, glossa; *lip.*, labial palpus.

A few insects, such as the grasshopper, katydids, crickets and others have a very different kind of "ear," not situated on the head, but on the abdomen (in the grasshoppers), front legs (in katydids and crickets), or elsewhere on the body. This kind of ear is composed of a small, thin vibratory drum or tympanum, with an air-space underneath it, and a tiny ganglion and special nerve in connection with it.

The sense of smell is very highly developed in most insects. Indeed it is probable that most of an insect's sensation of outside things comes through its organs of smell. And the

minute pits and cones or papillæ which are the organs of smell and are stimulated by substances in gaseous or otherwise very finely divided condition, may be very abundant, several thousand being present on each of the bee's antennæ.

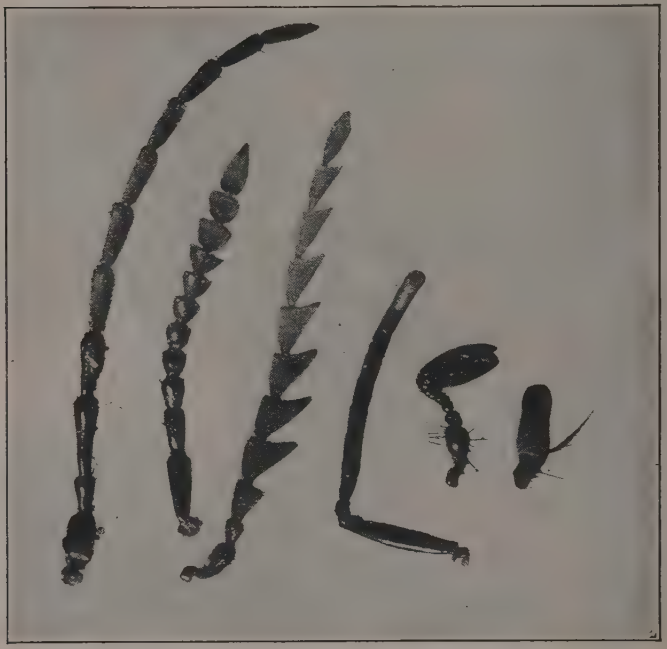


FIG. 52.—Different kinds of insect antennæ. 1, From a ground beetle, *Pterostichus californicus;* 2, from a carrion beetle, *Silpha ramosa;* 3, from a click beetle, *Melanotus variolatus;* 4, from a honey-bee, *Apis mellifica;* 5, from a Scarabæid beetle, *Ligyrus gibbosus;* 6, from a blow fly, *Calliphora vomitora.* (About 12 times natural size.)

Eyes and Sight.—On the head, also, beside the antennæ and mouth-parts, are the eyes. These are of two kinds, namely a pair of large compound eyes and three smaller simple eyes or

ocelli. The external surface of the compound eyes is revealed by the microscope to be divided into many small hexagonal facets. Each of these is a minute, rigid, flat lens behind which exists, arranged as a slender, rod-like organ, a perceptive unit of the compound eye. These units are called *ommatidia*, and each one is composed of a crystalline part just behind the external lens, surrounded by pigment, and behind this a sensitive nerve ending, called a *rhabdome*, also surrounded by pigment. From the rhabdome a fine nerve runs backward to join with the similar fine nerves from the other ommatidia to form the large *optic nerve* going to the brain. Each ommatidium is thus a complete little eye with light gathering and transmitting and perceiving apparatus, but without means of change of focus, and only slight means of adjustment to varying intensity of light.

FIG. 53.—Longitudinal section through a few facets and eye-elements (ommatidia) of the compound eye of a moth. *f.*, corneal facets; *cc.*, crystalline cones; *p.*, pigment; *r.*, retinal parts; *o.n.*, optic nerve. (After Exner; greatly magnified.)

This slight means of adjustment depends on the power of the insect to move the pigment surrounding the ommatidia back and forth, and thus to arrange it in a way to allow more or less light to reach the rhabdomes.

Most of the light rays that enter each ommatidium must be those that fall nearly vertically on the external lens, and pass vertically in to the sensitive rhabdome. Thus each ommatidium "sees" only any object or part of any object directly in the line of its long axis, and as the surface of the compound eyes of insects is usually strongly curved, separate ommatidia usually see only separate points in objects of the environment. These points put together side by side form a mosaic corresponding to the object or objects in front and at the sides of the eyes. Such seeing is called mosaic or apposed vision.

However, when the pigment surrounding the ommatidia is drawn back from their anterior ends, light rays can pass through the lateral walls of the ommatidia from the lenses of adjoining ommatidia, and thus the reflected rays from a single point in an object may reach and stimulate several adjacent rhabdomes, forming a picture in a somewhat different way from that by the strict mosaic method. This picture is called a superposition image as contrasted with the apposition image of the true mosaic vision.

The focal distance of the lenses in the compound eyes is usually about two yards, so that these eyes see objects best at that distance from the insect. The sharpness or clearness of the image formed depends, too, on the number and size of the separate ommatidia. The smaller and the more numerous they are the more perfect will be the mosaic; that is, the more complete and clear will be the picture seen. The number of facets in the compound eyes of insects varies from three or four to twenty thousand or more.

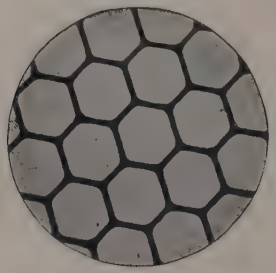


FIG. 54.—Part of corneal cuticle, showing facets, of the compound eye of a horse-fly, *Therioplectes* sp. (Greatly magnified.)

The simple eyes, or ocelli, are very different from the compound eyes in make-up. Each ocellus has but one lens, but behind it is a varying number of sensitive or optic cells each with anterior crystalline part and posterior retinal or percipient part. But the very short focus of the lens, usually but a few inches, and the primitive character of the structure of the part behind the lens, limit the vision probably to little more than a perception of shadows in imperfect outline. The ocelli can only perceive objects very close to the insect, and then with but little clearness. In fact the vision of insects, either by means of compound or simple eyes, is at best imperfect when compared with that of the vertebrate animals. Although observation and experiment have shown that insects can dis-

tinguish colors and pattern when the color shades and the outlines are strongly contrasted, yet on the whole insect eyes are much better constructed for quickly recognizing moving bodies and passing shadows than for seeing in detail either the shape or the color pattern of objects.

Legs.—The appendages of the bee's thorax are the legs and the wings. The thorax is composed of three closely fused body

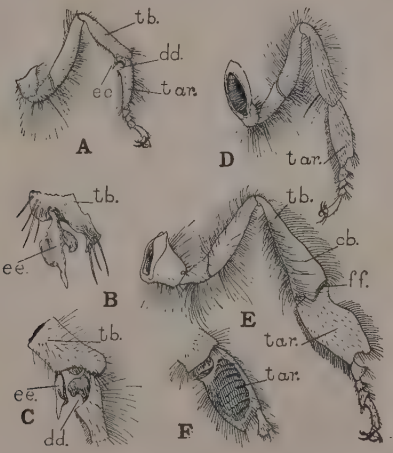


FIG. 55.—Legs of honey-bee. *A*, Left front leg of worker, anterior view, showing position of notch, *dd.*, of antenna cleaner on base of first tarsal joint, *tar.*, and of closing spine *ee*, on end of tibia *tb; B*, spine of antenna cleaner, *ee*, in flat view; *C*, details of antenna cleaner; *D*, left middle leg of worker, anterior view; *E*, left hind leg of worker, anterior or outer view, showing the pollen basket, *cb*, on outer surface of tibia, *tb* and the so-called "wax-shears," *ff*. *F*, inner view of first tarsal joint of hind leg of worker, showing rows of pollen-gathering hairs on tarsus, *tar*. (After Snodgrass.)

segments. Each of these segments bears a pair of legs, but only the hinder two bear pairs of wings. The legs of the bee are of the number characteristic of insects. However, some insects have the legs wanting. In such insects as have adopted a strictly sedentary life, as the scale insects, absence of the

legs is the rule rather than the exception. The bee's legs are well fitted for walking, but they are also modified, the hinder ones especially, for the performance of other functions. The fore legs carry a number of branched hairs and curved bristles for collecting pollen. They also have a curious little combination of structures called an antenna cleaner composed of a rounded indentation lined with a row of short spines and nearly closed by a large movable spine. The middle legs have also pollen-gathering hairs and a curved spine which is used to pry the pollen from the hindmost pair of legs. The hindmost legs are most modified of all. They have a so-called "pollen basket," or concave outer surface margined with curved bristles; "pollen combs" composed of transverse rows of short strong hairs; and, finally, a structure called the "wax-pincers," being the two opposed edges of two joints of the leg, one lined with spines, the other smooth. This structure, according to Casteel, has nothing to do with cutting wax, but aids in the gathering of pollen.

The separately articulated parts or joints of each leg have been given special names. Beginning with the one which articulates with the body, called the *coxa*, the others are the *trochanter*, a very small one, the *femur*, which is the largest, the *tibia*, which is next in size to the femur, and finally the *tarsal segments*, which, in the bee, are five in number. The last or terminal one bears a pair of claws and a little pad called the *pulvillus*, lying between the claws. These tarsal segments vary from one to five in different insects.

The legs of insects show great variety in structure and use. Aquatic insects have one or more pairs of the legs modified to be swimming organs; subterranean insects have digging legs; leaping insects have the hindmost pair usually very large and long. Some predaceous insects have the forelegs modified to be grasping or lacerating organs. In fact only those insects which use their legs exclusively for walking and running have them in a condition which might be called unmodified. In such insects they are usually long and slender with the segments more or less cylindrical in shape.

The last tarsal segments of the different legs can be called the

feet, for it is on the claws and little pads present on these segments that the insect stands. Insects that can climb on smooth surfaces or walk on overhanging walls have small hollow hairs on the pads of the feet from which a sticky secretion issues.

Wings.—Bees' wings are four in number, which is the typical number for insects in general. However, many insects, including all the true flies or Diptera, have but a single pair of wings. Parasitic insects, such as fleas, lice, etc., are usually wingless. All of the living wingless insects, except a single small group called the *Aptera*, are believed to have lost their wings by degeneration. The *Aptera*, however, are believed to be the immediate descendants of the primitive wingless ancestors of the whole great insect class.

The bees' wings are membranous, very thin and transparent, and supported on a framework of branching veins. The wings of many insects, however, are thickened, as for example the fore wings of grasshoppers and all beetles. The wing veins may be few in number as with the bee and house-fly, or many, as in the hind wings of the grasshoppers. Most of the butterflies and moths have their wings covered completely above and below with fine scales in which pigment of various colors is held. In the two-winged flies it is the hindmost pair of wings that is lost, or rather is replaced by a pair of very different structures, small stems with expanded tips, called balancers. In one small group of insects, however, it is the front pair of wings that is gone.

The two wings on each side of the bee's body can be fastened together, and are, when the bee is flying, by a row of tiny hooks along the front margin of the hind wing which catch hold of the hind margin of the front wing. This is a device which makes the bee practically two-winged when in flight. Some other insects, as most of the butterflies and moths, for example, also have means for fastening the two wings of each side together.

Sting.—The appendages of the abdomen, although several in number, are all combined to form the sting. This sting is made up of a sheath containing two movable barbed darts

and a pair of sting feelers which probably act as sense organs. The sting is connected by a duct with a poison reservoir which is supplied with poison from a pair of interior glands.

Wax Plates.—On the under side of each of the last four segments of the worker-bee there is a pair of wax plates. The wax issues as a fluid from small glands in these plates. On its issuance it spreads out over the surface of the plates and hardens. It can then be plucked off in thin sheets by the bee.

The Internal Structure of a Caterpillar

The body of the bee is too small to be dissected easily. For a study of the internal insect anatomy we may take a caterpillar; any kind will do, although one with a naked instead of hairy body will be more convenient to use. Although caterpillars are immature insects—they are the young stages of butterflies and moths—they will reveal all the important organ systems, except one, in well-developed condition. The one exception is the reproductive system, which may be examined in a full-grown grasshopper.

Adipose Tissue.—On opening the body of the caterpillar the first thing noted is a mass of whitish flocculent material which is fat, or adipose tissue. It is formed out of the surplus food eaten by the voracious caterpillar, and is used during the time which the insect spends in the chrysalis stage when it is inactive and cannot feed. This adipose tissue lies all around and over the various internal organs, and must be picked away to reveal them.

Alimentary Canal.—The most conspicuous organ visible, after the fat is removed, is the long straight alimentary canal running from mouth to anus through the middle of the body. It is composed of successive parts, named, beginning at the mouth, esophagus, *ventriculus* or stomach, small intestine, large intestine and rectum. Where the ventriculus and small intestine join, a few delicate, whitish, thread-like convoluted tubules arise known as the *Malpighian tubules*. These correspond in function to the kidneys of other animals, taking up and excreting waste from the blood.

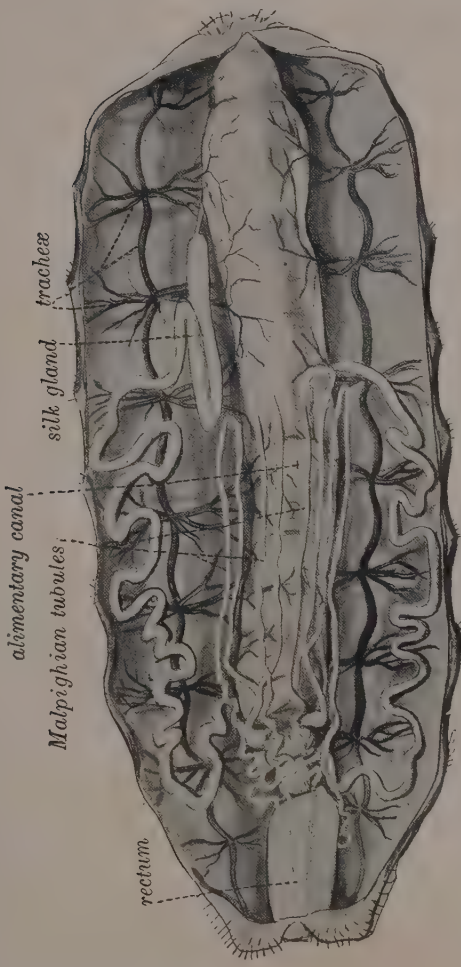


FIG. 56.—Dissection of the silk-worm, larva of the moth *Bombyx mori*.

If the caterpillar is of a kind that spins a coccoon when it is ready to change into a chrysalis, the silk glands will be found as a pair of long, smooth, rather thick, whitish cords lying one on each side of the alimentary canal and running forward to the mouth. Another pair of smaller, shorter tubes, not extending farther back than about the beginning of the ventriculus are the salivary glands. The silk glands are, indeed, only an enlarged and modified second pair of salivary glands.

Respiratory System.—In taking out the adipose tissue and alimentary canal there will be noted many dark little thread-like processes which are in reality fine tubes, called *tracheæ*. By tracing them to their origin they will be found to arise from larger tracheæ, which in turn are given off from main longitudinal trunks. There are two or four of these trunks, one or two on each side of the body, and from them arise not only the branches that by repeated subdividing extend to all parts of the body, but short strong lateral trunks that run to small openings called *spiracles*, or *stigmata*, in the sides of the body. In most caterpillars nine pairs of spiracles will be found, one pair on the prothoracic segment and the others on the abdominal segments, one pair to each. The spiracles and tracheæ are the organs of the respiratory system of the caterpillar, and similar organs, although varying much in number and arrangement, will be found in all insects, except a few very small and thin-skinned ones, which respire directly through the skin. The spiracles show on the outside of the body as small blackish spots, but are actually small openings in the body-wall, provided usually with valves or fringes of hairs to keep out foreign particles. They allow air to pass into the interior system of tracheæ, and carbon dioxide to pass out. The tracheæ, although thin-walled and delicate, especially the finer ones, are lined with a thin chitinous membrane in which are spiral thickenings which hold them open and give them a certain necessary elasticity. When the insect contracts certain muscles lying as longitudinal and circular bands along the inner side of the body-wall, the pressure of the body contents forces the tracheæ to close and expels the gas in them out

through the spiracles. When the muscles are relaxed and the pressure is removed the elastic-walled tracheæ open again and are filled with fresh air which rushes in through the open spiracles. One can readily see this alternate contraction and expansion, or respiratory movement, of the body in a live grasshopper.

The respiratory system of insects is, as we have learned from its condition in the caterpillar, very different from that of the vertebrate animals. There is no breathing through nostrils or mouth on the head; there are no lungs; there is no taking up and carrying of oxygen by the blood. The air that enters an insect's body through the spiracles is carried to every smallest part of it by the tracheal tubes. Similarly these tubes take up from the tissues and cells of the body waste carbon dioxide and carry it outside the body. The blood has nothing to do with respiration in insects. It only gets what air it needs for itself.

Circulatory System.—The blood of insects is better called blood lymph because it is always a mixture of blood and lymph. There is no elaborate system of arteries and veins, but only a single main longitudinal vessel which lies just under the body-wall of the middle of the back, and is sometimes called *heart*, but more often, simply, *dorsal vessel*. To see this organ in a caterpillar it is necessary to cut one open longitudinally along the middle of the underside and to take out carefully all the fat tissue and the alimentary canal. Then there may be seen running along the inner surface of the body-wall of the back a delicate membranous flattened tube which is composed of a number of successive chambers separated from each other by delicate valves and provided also with small lateral openings also furnished with valves. In the thin walls there are delicate muscle fibers, so that the vessel can contract and expand as these muscles are contracted and relaxed. This pulsation, combined with the arrangement of the valves, allows the blood lymph, which everywhere else in the body is not confined but flows freely among the body organs, to enter the dorsal vessel through the lateral openings and be forced

forward from one chamber to another until it issues from a narrow anterior extension of the vessel, called the *aorta*.

In many insects the dorsal vessel is not so long and slender as in the caterpillar, nor composed of as many chambers. But in all insects the circulatory system comprises nothing more than a pulsating dorsal vessel and the blood lymph flowing freely everywhere in the body cavity.

Nervous System.—Extending along the middle of the floor of the caterpillar's body will be seen a delicate white thread with small expansions or knots in it arranged segmentally, but wanting in the last two abdominal segments. In the head there

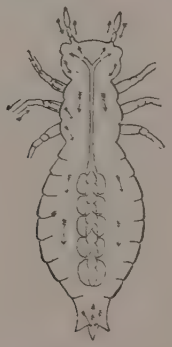


FIG. 57.

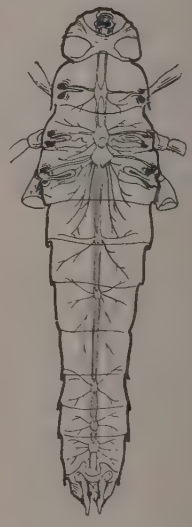


FIG. 58.

FIG. 57.—Diagram of circulatory system of a young dragon-fly; in middle is the chambered dorsal vessel, or heart, with single artery. Arrows indicate direction of blood-currents. (After Kolbe.)

FIG. 58.—Diagram of ventral nerve-cord of locust, *Dissosteira carolina*. (After Snodgrass.)

is a knot underneath the esophagus and from it a pair of stout threads which run up and around the esophagus, one on each side, and into a larger knot lying on top of the esophagus.

These knots and thread compose the main part of the central nervous system of the caterpillar, the threads being the nerve-

cords or connections, and the knots, the *ganglia*, or nerve centers. The ganglion in the head above the esophagus is called the brain, and from it nerves run to the eyes and antennæ. From the head ganglion under the esophagus nerves run to the mouth-parts. From the ganglia in the thoracic segments nerves run to the legs and to the strong thoracic muscles that move the legs. In insects with wings, nerves run from these ganglia also to the wing muscles. From the ganglia in the abdomen nerves run to the various body organs such as alimentary canal, dorsal vessel, tracheæ, muscles, etc. Thus although the head ganglia of an insect may be looked on as the most important nerve centers of the body, and one is called the brain, by analogy with the brain of vertebrate animals, yet really each ganglion is a little brain for its own part of the body, and there is a good deal more independence about the control of the different parts of the insect's body than there is in the vertebrate's body.

Although the ganglia and connecting longitudinal cord, or commissure, seem to be single knots and a single thread, they are in reality all double, each ganglion consisting of a pair fused together on their inner faces, and the connective commissure also is composed of two cords lying so close together as to seem but one.

In most insects there are not as many ganglia as we find in the caterpillars, the reduction in number being brought about not so much by the loss as by the fusion of ganglia. The typical six or seven abdominal ganglia may be fused to form but two or three or even one, and the three thoracic ganglia are also often fused to form a single one. In certain highly specialized insects, indeed, all the abdominal and thoracic ganglia join to form one large thoracic nerve center, or "body brain," as it has been called. Only in young insects and in adults belonging to generalized or primitive species, are there separate ganglia for most of the segments of the body.

Besides the central nervous system, most insects have also a sympathetic nervous system, which usually consists of a very small ganglion just in front of the brain, and one or two small

ganglia lying on the sides of the alimentary canal, all these ganglia being connected by fine nerve-cords.

Musculature.—Lying next to the skin of the caterpillar's body can be seen many muscles, some of them extending longitudinally and others as transverse or circular bands. Also in the head and thorax are many other muscles for moving the mouth-parts and legs. Most insect muscles are small and short, so that for the complete musculation of the body a great many separate muscles are required. Several thousand have been counted in the body of a single insect.

The muscles which lie against the inside of the body-wall in the caterpillar are repeated almost indentically for each segment. This musculation then can be said to be segmental in character just as we have found that the respiratory system, nervous system and even the dorsal vessel can be said to be segmentally arranged. That is, the internal systems of organs of the insect show as plainly, almost, as the external surface of the body, the fundamental segmental make-up. And they also show, just as the outside of the body does, the bilateral symmetry of the body. If the insect's body be cut longitudinally by a vertical plane it will be divided into equal halves, both external and internal organs either being in pairs, one member on each side of this vertical plane, or being made of fused pairs lying in this vertical plane.

Reproductive System.—As the caterpillar is only an immature moth or butterfly its reproductive system is not fully developed. Any adult insect of good size and not too hard wall may be used to study the organs of reproduction. A grasshopper will do very well.

In the female the eggs are produced in many small tubules, called *ovarioles*, which are grouped to form two *ovaries* (right and left) from each of which runs an *oviduct*. The two oviducts unite to form a single wider short tube called the *vagina*. From this the eggs pass out of the body in little packets. The eggs are fertilized while still in the body of the female by spermatozoa that have been received from the male and held in a small sac called the *spermatheca*. Each egg is inclosed in an inner, thin *vitelline membrane* and an outer thicker firmer

shell or *chorion*. But a small hole, called *micropyle*, is left at one pole in both these coverings, and through this a spermatozoan enters the egg while it is in the vagina, or a special posterior part of it called the *bursa copulatrix*.

The organs of the male that produce the spermatozoa are called *testes*, and correspond in position and function to the ovaries of the female. They are also composed of many tubules, but they are closely pressed together to form a small solid ovate mass. From each testis runs a duct, the *vas deferens*, through which the spermatozoa pass to reach the single *ejaculatory duct*, from which they are expelled by the male at mating.

FIG. 59.—Honey-bee, *Apis mellifica*, reproductive organs, sting and poison glands of queen, dorsal view. (Greatly magnified; after Snodgrass.)

TYPES OF MOUTH-PARTS

Corresponding to the great variety of food taken by insects is a great variety in structure of mouth-parts. The mouth-parts of the honey-bee, which laps up flower nectar, are very different from those of the grasshopper, which bites off and chews green leaves. And very different from either of these, again, are the mouth-parts of a butterfly or moth, or of a mosquito, or a squash-bug.

To the economic entomologist a knowledge of the kind of mouth-parts possessed by any insect pest is very important. For on the structure of its mouth will depend largely the kind of artificial remedy which must be devised to kill it. For example, if an insect pest of fruit trees has a piercing and sucking mouth, then spraying the surfaces of leaves with an arsenical poison will do little good, for it gets its food, plant sap, from the interior of the leaf or stem. But if it has a biting and chewing mouth then such a poison sprayed over the leaves may be

very effective. For with each bite of leaf the insect will get a little dose of poison, and a few such doses will kill it. Students of economic entomology should therefore pay special attention to insect mouth-parts. The following brief description of several different types of mouth parts may serve as an introduction to this study.

Mouth-parts of Grasshoppers.—A familiar type of the biting insect mouth is that of the grasshopper. Here the

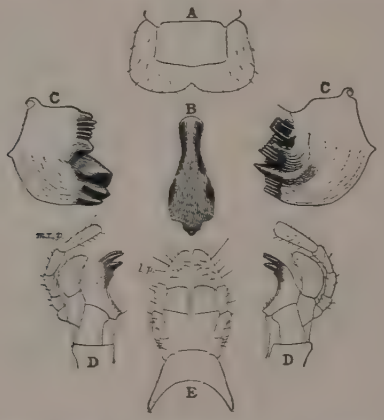


FIG. 60.—Mouth-parts of grasshopper. *a*, Labrum; *b*, tongue; *c*, mandibles; *d*, maxillæ; *e*, labium; *m.x p.*, maxillary palpi; *l.p.*, labial palpus. (Greatly magnified.)

upper lip or *labrum*, inclosing the mouth above is broad and flap-like, and the jaws, or *mandibles*, which like the honey-bee's, open and shut laterally, are large, strong, heavily chitinized and have their biting edges furnished with small tooth-like projections. The *maxillæ*, sometimes called second pair of jaws, which, with the mandibles, close the mouth at the sides, are each composed of several parts, movable on each other, of which one is a small feeler, or *maxillary palpus*, bearing at its tip many taste buds. The under lip, or *labium*, is a broad flap-like piece also made up of several articulating

parts of which two are feelers, or *labial palpi*, much like the maxillary palpi and also provided with taste buds at their tips. With the strong, hard-toothed jaws the grasshopper can bite off and crush not alone bits of soft green leaves but bits of plant stalks and even woody stems. The biting type of mouth-parts like the grasshopper's, although with many slight differences in the make-up of the various parts, is possessed by the cockroaches, crickets and katydids which belong to the same insect order as the grasshoppers, and also by the beetles, the dragon-flies, the white ants, and various other less familiar insects. All such insects bite off and chew more or less solid substances.

Mouth-parts of Cicadas, Squash-bugs, etc.—Cicadas, squash-bugs, bedbugs, and many other sap-sucking and blood-

FIG. 61.—Head and prothorax of water-bug, *Serphus dilatatus*. Showing the piercing beak and the first pair of legs which are fitted for grasping. (About natural size.)

sucking insects that belong in the same order with them have a slender, sharp-pointed, more or less firm piercing beak which is composed of a tubular sheath inside of which are four sharp needle-like pieces which can project out of the end of the sheath and be worked back and forth so as to lacerate plant or animal tissue and thus cause a flow of sap or blood which is sucked up the sheath into the mouth. The

four piercing stylets are the greatly modified mandibles and maxillæ, and the tubular sheath, which has a narrow longitudinal slit along its upper side, is the much modified labium. The labrum is reduced to a very small triangular piece at the base of the sheath, and the maxillary palpi are wanting. The labial palpi are also wanting, or are sometimes present as two small feelers rising from the base of the labial sheath. Insects with this type of mouth-parts have muscles running from the top of the pharynx or throat cavity to the top of the head which, when contracted, expand the pharynx and make a pumping or sucking organ of it.

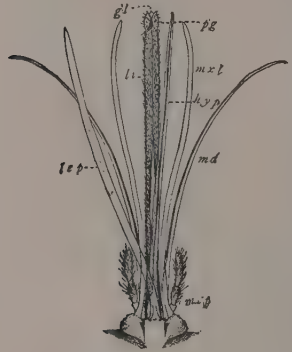


FIG. 62.—Mouth-parts of a female mosquito, *Culex* sp. *lep.*, Labrum-epipharynx; *md.*, mandible; *mx.l.*, maxillary lobe; *mx.p.*, maxillary palpus; *hyp.*, hypopharynx; *li.*, labium; *gl.*, glossa; *pg.*, paraglossa.

Mouth-parts of Mosquito.—The piercing and sucking beak of the mosquito is made up in much the same way as that of the squash bug and cicada. That is, there is a tubular sheath, narrowly open from base to tip along the middle of its upper side, in which lie a number of sharp, slender stylets, which can project beyond the edge of the sheath and pierce or lacerate plant tissue or the skin of animals. The sheath is the much modified under lip or labium, while the needles are the modified mandibles and maxillæ and two additional ones called *labrum-epipharynx* and *hypopharynx*. That is, they are outgrowths from the upper and lower walls of the mouth or throat (pharynx). Thus the mosquito has six piercing needles held together in its beak, instead of four as with the cicada and squash-bug and their allies. Or rather this is true only of the female mosquito, for the male mosquito lacks two of the stylets, probably the mandibles, and never, or but rarely, pierces the skin of animals to suck blood. There is

also a pair of maxillary palpi, as long as the beak in both males and females of some mosquitoes, but shorter in the females of most species.

Mouth-parts of House-fly.—The mosquitoes belong to the order of two-winged flies, but their mouth-parts cannot be taken as typical of the order. A house-fly, for example, has a mouth very different in make-up. The labium is a fleshy proboscis expanded at the tip to form a special lapping and rasping organ, and there are no mandibles or maxillæ, at least in functional condition. There is one pair of short

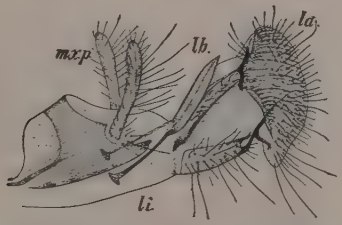


FIG. 63.—Mouth-parts of the house-fly, *Musca domestica*. *lb.*, Labrum; *mx. p.*, maxillary palpi; *li.*, labium; *la.*, labellum.

palpi which are usually called the maxillary palpi, although they may really belong to the labium. The house-fly takes up food either by lapping liquids with the broad tongue-like end of its proboscis, or by rasping off bits of solid food, pouring out saliva over them and then lapping them up as a fluid mixture. The end of the proboscis, which is called the *labellum*, is very elaborately contrived and furnished with ridges for rasping and special muscles for folding and unfolding.

Mouth-parts of Butterflies and Moths.—The sucking tube of the butterfly or moth is still another very different type of mouth. There is no labrum, mandibles nor labium, or only rudiments of them. But the maxillæ are developed into a pair of long, slender, coiling pieces or processes which can be held together in such a way as to form by means of their grooved inner faces a perfect tube, long, slender and flexible. With this tube they suck out nectar from the nectaries

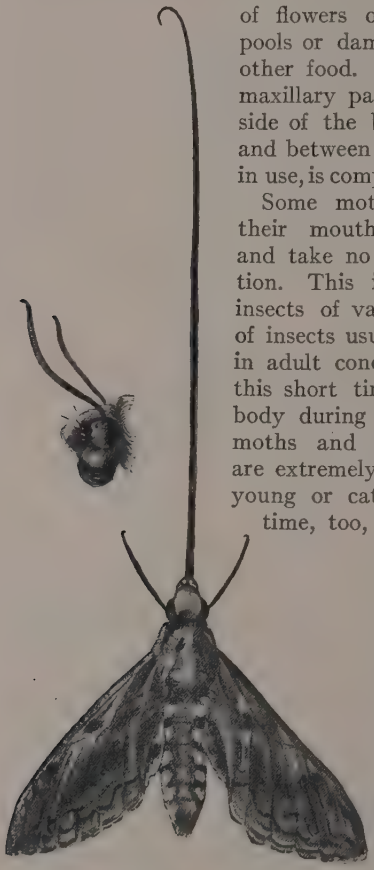


FIG. 64.—Sphinx moth, showing proboscis. At left the proboscis is shown coiled up on the underside of the head, the normal position when not in use. (Large figure natural size; small figure twice natural size.)

of flowers or drink water from little pools or damp places. They take no other food. There is a pair of tufted maxillary palpi which rise from each side of the base of the sucking tube and between which the tube, when not in use, is compactly coiled.

Some moths and butterflies have their mouth-parts wholly atrophied and take no food in their adult condition. This is true also of numerous insects of various kinds. Such kinds of insects usually live but a short time in adult condition, and use up during this short time the fat stored in the body during the immature life. The moths and butterflies, for example, are extremely voracious feeders in their young or caterpillar stages. At this time, too, they have mouth-parts of very different type from those possessed in adult life. A caterpillar's mouth-parts are of biting type with strong cutting and crushing mandibles and the food is the tissues of plant leaves and stems. Thus it is important in the study of insect mouth-parts to recognize that they may be very different in the same insect at different times of its life, and that, therefore, the injuries caused by an insect, and the rem-

edies for these injuries, may be very different in different stages of the insect's life.

Development and Metamorphosis

Although moths and butterflies are hatched from the egg in a condition extraordinarily different in appearance from that which they finally assume, not all insects undergo so great a metamorphosis during their development. For example, a just-hatched grasshopper is unmistakably grasshopper-like in

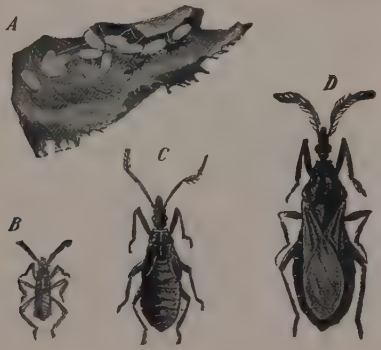


Fig. 65.—Metamorphosis, incomplete, of an assassin-bug (family *Reduviidæ*, order *Hemiptera*). *A*, Young just hatching from eggs; *B*, young after first molting, showing beginning wing-pads; *C*, older stage with larger wing-pads; *D*, adult with fully developed wings. ($\frac{1}{2}$ larger than natural size.)

appearance, although it has no wings and the proportions of the different parts of its body are somewhat different from those of its parents. The young grasshopper has three pairs of legs, has a head with antennæ, compound eyes and biting mouth-parts like those of its parent, walks and hops about, feeding on green plants, and altogether looking and acting much as fully developed grasshoppers do, except that it has no wings and hence cannot fly. As it grows, however, wings begin to appear as tiny bud-like expansions on the back of the two

hinder thoracic segments. These wing-buds rapidly increase in length, and by the time the developing grasshopper has come to its adult size the wings are also full size and ready for use.

During this growth and development of the young grasshopper, which requires several weeks for its completion, it molts several times. This molting is the shedding of the chitinized cuticle which covers the body. Before each molting takes place, however, the skin cells have secreted a soft and colorless new chitinized cuticle which, as soon as the outer old one is cast off, becomes firm and colored, and takes its place. The young grasshopper shows most of its changes in size and appearance just after each molting. The wing-buds hardly seem to grow between molting periods, but after each molting they may be seen to be larger and more developed.

Insects whose development is, in general, like that of the grasshopper, that is, those which hatch from the egg in a condition more or less resembling the parent except for size and total absence of wings, are said to undergo a development without metamorphosis or with *incomplete metamorphosis*. While insects which, like the moths and butterflies, hatch from the egg in a stage very different in appearance from that of the parent, and in their development have to undergo extraordinary changes in appearance and structural make-up to become like the parent, are said to develop with metamorphosis, or with *complete metamorphosis*.

In insects with complete metamorphosis there is a curious stage called the *pupal* or *chrysalid* stage which is interpolated between the first or *larval* stage, which is that in which the insect hatches, and the final or adult stage, the stage in which the insect is sometimes called an *imago*. After the young caterpillar has undergone a certain period of rapid growth and increase of size, during which period it molts several times but does not show any external changes making it any more like its parent than it was at the beginning, it stops feeding and changes into an inactive, non-feeding stage with its body inclosed in a thick, firm, chitinized covering which is neither of the shape of the larva nor of the imago. This is the so-called pupal stage, and the insect in this condition is called a *pupa*.

It is in this stage that most of the radical changes in structure are undergone which are necessary to make the moth or butterfly out of the caterpillar, the house-fly out of the maggot, or the beetle out of the grub.

However, most of these changes have their beginnings during the larval stage. For example, little wing buds have been developing all through the larval life, but they have remained very small and invisible underneath the chitinized cuticle of the larva. Especially in the last few days of the larval stage are the various changes going on rapidly. But they are so radical in

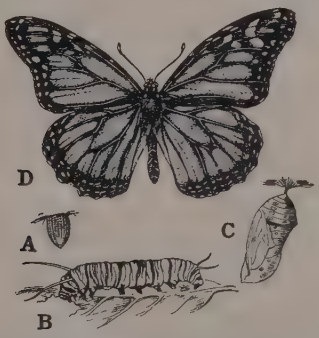


FIG. 66.—Metamorphosis, complete, of Monarch butterfly, *Anosia plexippus*. *a*, Egg (greatly magnified); *b*, caterpillar or larva; *c*, chrysalid or pupa; *d*, adult or imago. ($\frac{1}{2}$ natural size; after Jordan and Kellogg.)

character that it is impossible for the insect to maintain an active food-getting life and make the changes at the same time. Hence comes the necessity for the quiescent pupal stage in which the insect, living on food stored up as fat by the larva, and safely inclosed in a hard protecting shell, can make the great changes necessary to its becoming a fully developed winged imago, different as to mouth-parts, eyes and antennæ, different as to body shape, different as to legs and abdominal appendages, and, together with all these structural differences, radically different as to habits and behavior. Many of the

internal systems of organs undergo as radical changes as the external parts. Muscles, salivary glands, parts of the alimentary canal, etc., of the larva break down and are used as food by new growth centers which develop into new muscles, new salivary glands and other new internal parts. This internal degeneration of larval parts and rebuilding of imaginal parts are called *histolysis* and *histogenesis*, and form a fascinating subject of study, which requires, however, a training in histologic methods of technique beyond that of the elementary student.

In the next chapter, which is devoted to the classification of insects, we shall point out the character of the metamorphosis and some of the special features of development presented by each of the different insect orders.

CHAPTER XVII

THE CLASSIFICATION OF INSECTS, AND INSECT BENEFITS AND INJURIES

Linnaeus, the first great classifier of animals, divided the insects into seven orders based on the character of the wings. In the order Aptera, or wingless insects, he placed all insects lacking wings. But now we know that there are wingless moths, wingless beetles, wingless flies, and so on, and that these different kinds of insects ought not to be classified together simply because through degeneration from one cause or another they have lost their wings.

The two-winged insects with balancers in place of the hind wings Linnaeus called Diptera, and this order still stands about as he established it. All the four-winged insects with membranous wings he placed in two orders, those having stings in the Hymenoptera and those without stings in the Neuroptera. Insects with their wings covered with scales he called Lepidoptera, and insects with their fore wings thickened he called Coleoptera if the wings were thickened for their whole length, and Hemiptera if their wings were thickened only over the basal half.

Although now different criteria are used as a basis for insect classification and the class Insecta is divided into more than seven orders, Linnaeus's seven ordinal names are still used, and the insects indicated by each of them are largely also characterized by the condition of wings indicated by the names. But out of the Linnaean orders Aptera and Neuroptera, nine different new orders, beside the two still bearing the same names, have been made. And three other new orders have been made for insects taken from the Hemiptera and the Coleoptera. In all we now recognize nineteen orders in the class Insecta. This, at least, is the American practice. Most

English and Continental entomologists do not recognize so many different orders.

The two principal criteria used in the modern classification of insects are the structure of the mouth-parts and the character of the development. Of these, the development condition is held to be the more fundamental, although this may be open to question. However, on a primary basis of development and mouth-part conditions, combined with character of wings, antennæ, and to a less extent, of legs and abdominal appendages, insects are now classified into orders in the following way:

Metamorphosis very slight; biting mouth-parts; wingless	APTERA
Metamorphosis incomplete.	
With biting mouth-parts.	
Wings membranous	EPHEMERIDA
	PLECOPTERA
	ODONATA
	ISOPTERA
	CORRODENTIA
Fore wings parchment-like	ORTHOPTERA
	EUPLEXOPTERA
Wingless	MALLOPHAGA
With sucking mouth-parts	HEMIPTERA
	THYSANOPTERA
Metamorphosis complete.	
With biting mouth-parts.	
With wings membranous	NEUROPTERA
	MECOPTERA
	TRICHOPTERA
With fore wings thickened	COLEOPTERA
With sucking mouth-parts	LEPIDOPTERA
With lapping or piercing and sucking mouth-parts	DIPTERA
	SIPHONAPTERA
	HYMENOPTERA

Order Aptera.—The *Aptera* undoubtedly include the most primitive of living insects. This primitiveness is shown not alone by the absence of wings, which is the characteristic which gives the order its name, but is manifest also in the very simple and generalized condition of most of the body parts, internal as well as external.

All the insects of the order are small, but a group of them

known as the spring-tails, or *Collembola*, are very small indeed, most of them measuring only two or three millimeters in length. These *Collembola* are more specialized in structure than the other *Aptera*, and represent a side line of evolutionary development within the order. Most of them possess a curious forked spring on the under side of the body by means of which they leap vigorougly when disturbed. But few of these minute insects are injurious, although at least one species, called the garden-flea, *Smynthurus hortensis*, is sometimes found in considerable numbers upon the leaves of young cabbages, turnips, cucumbers and various other plants, on which it probably feeds. Certain other species are reputed to exist in such abundance in the soil of flower and vegetable beds as to keep the soil so constantly disturbed by their movements that the roots cannot hold the plants firmly.

FIG. 67.—The spotted spring-tail, *Papirius maculosus*, with spring extended. (Natural size, two millimeters.)

FIG. 68.—Young and adult *Lepisma* sp. from California. (Twice natural size.)

The other principal group in the order, known as the *Thysanura*, is represented in this country by three small families which contain but a few species. All the *Thysanura* have a soft flattened body of from but a few millimeters to three-fourths of an inch in length, and live mostly under stones and logs in the soft soil and humus at the bases of tree trunks. A common species that occurs in houses is known as the silver-fish, or fish-moth, *Lepisma saccharina*. It is about one-half an inch long and silvery white with a yellowish tinge. It feeds

chiefly on sweet or starchy materials, sometimes doing real damage in libraries, where it attacks the book bindings. It attacks starched clothing, eats the paste off the wall-paper, causing it to loosen, and infests dry starchy foods. It runs swiftly and avoids the light. It can be killed by spreading pyrethrum powder in book cases, wardrobes and pantries. Another species, called the bake-house silver fish, *Lepisma domestica*, is often common about fire places and ovens, running over the hot metal and bricks with surprising immunity from the effects of the heat.

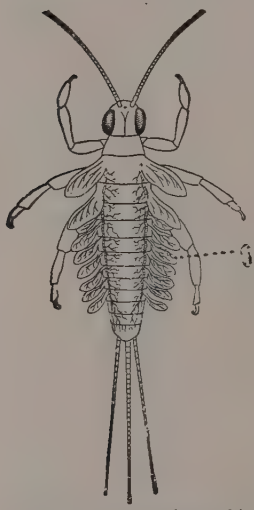


FIG. 69.—Young (nymph) of May-fly, showing (*g*) tracheal gills. (Three times natural size; after Jenkins and Kellogg.)

All of the *Aptera* when hatched from the egg very much resemble, except in the matter of size, the parent form. And they reach the adult condition with very little change except that of a marked growth in size.

Order Ephemerida.—The *Ephemerida*, or May-flies, or lake-flies, are a small order of delicate four-winged insects which live in adult condition for from but a few hours to a few days, varying with different species. They have soft, poorly developed mouth-parts of biting type, or no mouth-parts at all, and probably only a few kinds take any food as adults. The wings are very thin and many veined, with the hind wings smaller than the fore wings, or even wholly lost in a few species.

The eggs are dropped into the water of ponds or quiet stream pools, and the young which hatch from them are soft-bodied flat creatures, called nymphs, which crawl about on the bottom, often on the undersides of stones. They have well-developed biting mouth-parts with sharp-pointed mandibles. They

breathe by means of delicate leaf-like tracheal gills on the sides of the abdomen, and when ready to change into adult condition, crawl up out of the water onto the bank or plant stems or float to the surface, and there quickly cast the nymphal cuticle and issue as winged imago. Some species molt again after having used their wings a little while.

The May-flies often issue from rivers or lakes in enormous numbers in the summer, and form an annoying plague to house-boat dwellers or summer cottagers simply by their too abundant presence. Their dead bodies falling on the surface of the water are sometimes driven by the wind on the shore in great windrows.

FIG. 70.—Young (nymph) of stone-fly, from California. (Twice natural size.)

Order Plecoptera.—The *Plecoptera*, or stone-flies, are unfamiliar insects which, like the May-flies, hatch from eggs dropped into the water, and live an immature life of several months as flattened wingless nymphs crawling about at the bottom. Indeed, the stone-fly nymphs often live side by side with the young May-flies, but can usually be distinguished from them by being thicker and broader, and having tracheal gills not leaf-like but composed of separate filaments or tufts of such filaments rising from the thoracic segments, one tuft just behind each leg. They cannot live in stagnant water or foul streams. When ready to change to the winged adult condition the nymphs crawl out from the water, the cuticle splits along the back, and the winged fly issues.

The adult flies have four rather large, membranous, many-veined wings, the hind ones being larger than the front ones. The mouth-parts are well developed and fitted for biting, but the food habits are not known. About 100 species occur in North America, among which there is none injurious to man. The young of many kinds furnish food for many fishes. And this is true also of the May-flies.

Order Odonata.—The *Odonata* are the familar dragon-flies, devil's darning-needles, and damsel-flies, that swoop about over ponds and quiet streams, capturing small flying insects. The body is long and slender, and the four wings are membranous, many-veined, and all about equal in size. They live largely on the wing and are among the most rapid and powerful insect fliers. The legs are slender and weak, and chiefly used to hold captured prey up to the mouth and for perching. Like the May-flies and stone-flies, their young stages are spent in water as wingless, crawling nymphs. Here also they capture smaller

FIG. 71.—Adult and last exuvia of the white-tail dragon-fly, *Plathemis trimaculata*. (Natural size.)

living insects, not however by speedy pursuit but by lying in wait and seizing any unwary prey that may come within reach of the curious extensile under lip which is provided with sharply toothed, jaw-like pincers.

About 300 species of *Odonata* are known in North America, and 2000 in all the world. All of them have beautifully colored bodies, and many have the wings strongly patterned by conspicuous brown blotches and bands. None of them is injurious to man, but almost all may be considered as beneficial, because they are all destroyers of noxious insects. It is

probable that dragon-flies are the most efficient natural remedy for mosquitoes. As nymphs they destroy many mosquitoes in their young or "wriggler" stage, while as adults they capture hosts of flying mosquitoes.

FIG. 72.—Young (nymph) of a dragon-fly, *Sympetrum illotum*. Showing the lower lip extended. (Natural size.)

Order Isoptera.—The order *Isoptera*, termites, or so-called white ants (although not related to the true ants) comprises less than ten species in North America, but is much better represented in subtropical and tropical regions. In equatorial Africa and South America, for example, the termites are very important insects both because of their numbers and because of their habits. They have strong biting mouth-parts, and they feed chiefly upon dead wood. By virtue of this habit they may be of considerable benefit as scavengers, or of considerable harm by destroying wooden poles, furniture, etc. They live in large communities, usually making their nests underground or in "houses" built of soil brought up laboriously grain by grain and fastened together so as to produce earthen structures rising like tents or pinnacles for several feet above the surface of the ground.

The communities comprise kings and queens (males and females) provided with four nearly equal, delicate, membranous

wings, wingless workers, and wingless soldiers. The soldiers have greatly enlarged mandibles which are used in fighting enemies. The workers are smaller than soldiers or kings and queens, but exist in larger numbers and get the food and build the nest for the whole community. After a marriage flight the queens find hiding places in the ground, break off their wings, and each lays a few eggs from which begins a new community. The young are all alike when first hatched, and only workers or soldiers develop from the first eggs. Later

FIG. 73.—Termite queen, worker and soldier. (Natural size.)

eggs give birth to young which develop wing buds and after several moltings become fully formed winged individuals.

Only one species, *Termes flavipes*, is found in the eastern states. Its workers are about 1/5 of an inch long, white and soft-bodied. The soldiers are a little larger, and the winged males and females, which go from the nest and swarm in the air in late spring or late summer, are chestnut brown to blackish and but little longer than the workers. This species usually makes its nest in or under old logs or stumps. It sometimes does damage by mining the foundation timbers

of houses, and in the southeastern states they have been found infesting living plants, particularly orange trees, guava bushes, sugar cane and pampas grass. The largest and most abundant species, *Termopsis augusticollis*, on the Pacific coast, makes its nest by mining in dead stumps and logs and sometimes ruins telephone and telegraph poles in this way. A single community of this species may include thousands of individuals.

Order Corrodentia.—The order *Corrodentia*, or book-lice and bark-lice, is composed of very small insects most of which, composing the family *Psocidæ*, have two pairs of wings and a plump rounded body, while the others, forming the family *Atropidæ*, have no wings or only small wing scales or buds and a flattened body. The Psocidæ are the bark-lice and are commonly found in small clusters on bark, while the Atropidæ are the so-called book-lice, common in old books and on dry dead organic matter.

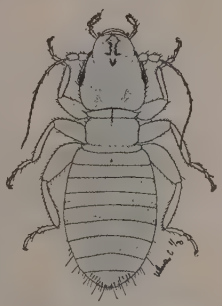


FIG. 74.—A wingless book-louse, *Atropos* sp. (Much enlarged.)

In both families the mouth-parts are of the biting type, with the jaws especially strong and heavy for the successful biting off and chewing of hard dried food. *Atropos divinatoria* is the species usually found in books. It is about 1/25 of an inch long, grayish-white, with slender projecting antennæ, and small eyes looking like distinct black spots on the head. It does not limit its feeding to the paste of book bindings but does much damage to dried insects in collections.

Order Mallophaga.—The *Mallophaga*, or biting bird-lice, compose a group of about 1500 known species, all of which live as external parasites on the bodies of birds and mammals. They have strong biting mouth-parts, and feed exclusively on the hairs or feathers of their host. They do not, like the true lice, suck blood.

The body varies from 1/25 to 1/3 of an inch long, is wholly wingless and much flattened. The insects have no compound

eyes, and in this and their winglessness show the degeneration which a parasitic life almost always produces. The eggs are fastened to the hairs or feathers, and the young undergo little change during their development except an increase in size to become like the parents.

Almost every species of bird or mammal is infested by one or more kinds of *Mallophaga*, and sometimes the host must suffer much annoyance and even injury from the irritation produced by its many small parasites. All of the common barnyard birds are troubled more or less by these biting lice, and their presence may become a serious matter in hen-houses. An account of certain special Mallophagan pests and of remedies for them is given in Chapter XXX.

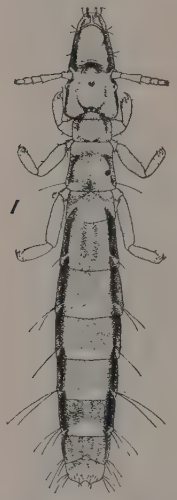


FIG. 75.—A biting louse of pigeons, *Lipcurus baculus*. (Natural size indicated by line.)

Order Orthoptera.—The order *Orthoptera* is much larger than any of the other orders so far considered, and includes many familiar insects, such as the grasshoppers, katydids, crickets, cockroaches and praying mantises. The order is divided into six families, of which three include all the well-known singing insects, except the cicada or harvest flies. The insects in these three singing families are also the best known leaping insects, the hind legs being especially long and strong, so that when the insect is at rest the "knee joints" of these legs stand up conspicuously above the body.

All the *Orthoptera* have strong biting mouth-parts and nip off and chew their food, which is usually green leaves and stems. The mantises (family *Mantidæ*) are, however, predaceous, preying on other insects, and the cockroaches (family *Blattidiæ*) prefer dried vegetable or animal matter. The metamorphosis is incomplete, and the young, which resemble the parents

except in size and the absence of wings, have the same feeding habits and the same haunts as the adults. The name of the order is derived from the straight-margined parchment-like fore wings (*orthos*, straight, and *ptera*, wings) which are chiefly used as covers to protect the large membranous hind wings on which the flight function depends. There are numerous wingless species in the order, and some with degenerate short wings incapable of flight.

The "music" which is made by the male crickets, katydids and meadow-grasshoppers, is produced by the rubbing together of the bases of the fore wings in which certain veins are thickened and roughened so as to make effective stridulat-

FIG. 76.—The American locust, *Schistocerca americana*. (Natural size.)

ing organs. Grasshoppers make sounds when at rest by rasping the inner surface of the broad hind legs across the outer surface of the folded fore wings, and while in flight many of them make a loud clacking sound by striking the front margin of the hind wings back and forth past the hinder margin of the thickened fore wings.

Despite the beneficial feeding habits of the insect-preying mantises, the *Orthoptera* as a whole must be looked on as a seriously injurious group of insects. Cockroaches are great pests in houses, while crickets and especially grasshoppers work much injury to field crops. The notorious Rocky Moun-

tain Locust, *Melanoplus spretus*, which used to appear occasionally in countless numbers in the grain fields of the Mississippi valley, travelling a thousand miles by a single flight from the Rocky Mountain plateau, is no longer such a danger, but there are many other non-migratory species of grasshoppers which constantly attack the field crops. Some of these injurious *Orthoptera* are referred to in Chapter XXXVI and remedies for their attacks described.

Order Euplexoptera.—The *Euplexoptera*, or earwigs, comprise a small number of insects which were formerly included in the *Orthoptera*. They are small brownish or blackish insects readily recognized by the curious forcep-like appendages on the tip of the abdomen. They are either winged or wingless, and when winged have small thickened wing-covers extending only about half way to the tip of the abdomen with the well-developed, nearly hemispherical hind wings compactly folded underneath them. Earwigs are nocturnal in habit, and feed by means of their biting mouth-parts on ripe fruit, flowers and other vegetable food. Despite the name they have nothing to do with ears. The young undergo an incomplete metamorphosis, and closely resemble the parents, except in size, from the time of their hatching.

Order Hemiptera.—The *Hemiptera*, or sucking bugs, cicadas, aphids, scale-insects, etc., compose a large order which includes over 5000 species in North America, representing a large variety of insect life. Many of them are of great economic importance. Some of the most destructive crop pests and most discomforting insect scourges of man and the domestic animals belong to this order. The chinch-bug of the corn and wheat fields of the Mississippi valley, the tiny sap-sucking aphids or plant-lice and phylloxera, and the insignificant-looking scale-insects cause annual losses of millions of dollars to American fields, orchards and vineyards.

The mouth-parts in all the *Hemiptera* are arranged to form a piercing and sucking beak capable of taking only liquid food. This food is usually the sap of living plants or the blood of living animals. The wings are typically four in number, although some species have but two wings and others none.

The *Hemiptera* have an incomplete metamorphosis, the young at birth resembling the parents in most essential characteristics except size and the presence of wings.

The order is sub-divided into three sub-orders, one, the *Parasita*, composed of wingless species living as parasites on man and other mammals; another, the *Homoptera*, winged species with fore and hind wings of the same texture throughout and usually held sloping or roof-like over the back; and

FIG. 77.—A water-bug, *Serphus dilatatus*. (Natural size.)

another, the *Heteroptera*, with four wings held flat on the back when folded and with the bases of the front wings thickened, hence the name of the order (*hēmi-*, half, *ptera*, wings). The *Parasita* include the sucking lice; the *Heteroptera* the squash-bugs, chinch bugs, water-boatmen, assassin-bugs and stink-bugs; while the *Homoptera* include the cicada or harvest-flies, the tree- and leaf-hoppers, the aphids, or plant-lice and the degenerate scale-insects. Some of the more injurious species of this order are described in Chapters XXX to XXXVII.

Order Thysanoptera.—The curious little insects known as thrips, or fringe-wings, which used to be classified with the *Hemiptera*, are now given the standing of an independent small order. This is due to the peculiar character of their mouth-parts and feet, and to the interesting nature of their development, which is apparently of a sort of transitional condition between incomplete and complete metamorphosis. The food of the thrips is either the sap of living plants or moist decaying vegetable matter, especialy wood and fungi. The mouth is of sucking type with needle-like mandibles and maxillæ to pierce plant tissue, but it is curiously asymmetrical, the right mandible being wholly wanting and the upper lip being more expanded on one side than the other. The feet have a small protrusible membranous sac or bladder at the tips instead of fixed claws or pad. These tiny sacs probably fill some special rôle in enabling the thrips to hold on to leaves or flower surfaces.

While most of the thrips species live on wild plants, a few infest fruits, grains and vegetables, and do much injury. Among these are the onion thrips, wheat thrips, grass thrips, orange thrips and pear thrips. This last pest appeared suddenly in California a few years ago, and since then has caused the loss of millions of dollars worth of prunes, apricots and other deciduous fruits. Several of the thrips are described in the later special chapters on injurious insects.

Order Neuroptera.—The *Neuroptera*, constituting a small order in point of numbers, are insects with biting mouth-parts, and a metamorphosis usually called complete, but in which the larval stage resembles somewhat the adult stage, and the pupal stage is not usually undergone as a wholly immobile chrysalid, but more often in a condition which suggests that of an inactive larva with conspicuous external wing-pads. This stage is usualy passed in a special cell or cocoon made by the larva when full grown. The adults have four membranous, many-veined or so-called "nerve-veined" wings, hence the name of the order (*neuron*, nerve, *ptera*, wings). The *Neuroptera* include seven families of mostly unfamiliar insects, some very large, and others extremely small. The immature stages of

one family, the *Sialidæ*, of which the large dobson-fly or hellgrammite is the best known species, are passed in the water of streams or ponds, but the members of all the other families are terrestrial through all their life. Of these the ant-lions, whose larvæ make small pits in loose soil in which to catch prey, and the aphis-lions, lace-winged flies and snake-flies, whose sharp-jawed larvæ feed on such small defenseless insects as aphids and codling moth larvæ, are more or less familiar and may be counted as beneficial insects. There are no seriously injurious insects in the order.

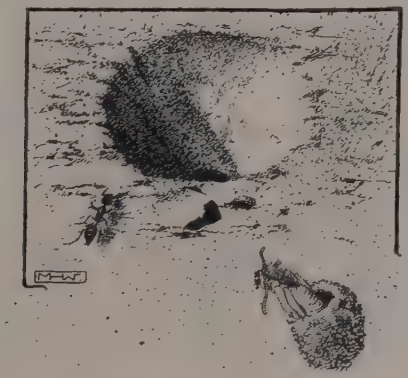


FIG. 78.—Pit of ant-lion, and, in lower right-hand corner, pupal sand-cocoon, from which adult has issued, of ant-lion, *Myrmeleon* sp. (About natural size.)

Order Mecoptera.—The order *Mecoptera* includes a few little-known insects called snow-fleas and scorpion-flies. The mouth-parts are of biting type, and are elongated to form a sort of short, blunt beak. The metamorphosis is complete. Most of these insects are probably predaceous in habit, feeding on other small insects, and thus perhaps doing good, but some take only animal food found dead. The curious snow-fleas, *Boreus*, are minute, black, leaping creatures that appear on snow in winter time, and in summer live on tree trunks or in

moss. The scorpion-flies have four, rather long, slender, membranous wings with numerous veins, and long angular legs, with which they scramble awkwardly about among green or drying grass leaves.

Order Trichoptera.—The *Trichoptera*, or caddis-flies, compose a small homogeneous order of four-winged insects many of which look much like moths. In fact, there is little doubt that this order may be looked on either as the direct ancestors of the moths and butterflies or as a group descended from such ancestors. The wings are membranous, but obscurely colored by a covering of hairs and narrow scales; the antennæ are long and slender, and the legs delicate and unmodified. The insects limit their flight to short, uncertain excursions along the shore of the stream, and spend long hours in the close foliage of the bank. So far as observed they take no food, although they have fairly well-developed mouth-parts fitted, apparently, for lapping up liquids.

The eggs are dropped into water and the aquatic larvæ build protecting cases (hence the name, case- or caddis-flies) of little pebbles, sand, or bits of wood fastened together by silken threads. Some of the cases can be carried about by the larva in its ramblings, but others are fastened to the boulders or rock-beds of the stream. The larvæ are caterpillar-like, with head and thorax that project from the case, usually brown and firm-walled, while the abdomen is soft and whitish. They breathe by means of thread-like tracheal gills, and feed on bits of vegetable matter and probably other small aquatic creatures. Some have the interesting habit of spinning a tiny silken net stretched in such a way that its broad shallow mouth is directed up-stream so that the current may bring food into it. When the caddis-worm is ready to pupate it withdraws wholly into the case and closes the opening with a loose wall of stones or chips and silk. When ready to issue the pupa usually comes out from the submerged case, crawls up to some support above the water, and there the winged imago emerges. Some kinds, however, emerge in the water.

About 500 species of caddis-flies are known of which 150

occur in North America. None of them is injurious. The larvæ of many species are eaten by fish.

Order Coleoptera.—The great order of *Coleoptera*, or beetles, is the largest of all the insect groups, and many of its members are among the most familiar of our insect friends and enemies. More than 12,000 species are known in North America north of Mexico. They represent nearly 2000 genera grouped into 80 families. The classification of the Coleoptera is one of the most difficult subjects in the study of systematic entomology, and but few entomologists know more than a few score or few hundred of the commoner kinds. The beetles are mostly readily distinguished by their horny fore wings, or *elytra*, which serve as protecting covers for

FIG. 79.—Water-tiger, the larva of the predaceous water-beetle, *Dyticus* sp. (Natural size.)

FIG. 80.—The predaceous water-beetle, *Dyticus* sp., pupa and adult. (Natural size.)

the large membranous hind wings. They all have strong biting mouth-parts and a firm dark chitinized cuticle or outer body-wall. The body is usually short and robust with its segments well fused together. There is much variety in the character of the antennæ and feet, and these differences are largely relied on in classifying beetles into different families.

The eggs are laid underground, or on leaves or twigs or in branches or trunks of live trees, in fallen logs or in decaying

matter, in fresh water, etc., and from them hatch larvæ, usually called grubs, with three pairs of legs (sometimes wanting), biting mouth-parts, simple eyes and small antennæ. These larvæ may be predaceous, as water-tigers (larvæ of water-beetles), or plant feeders, as the larvæ of the long-horn and leaf-beetles, or carrion feeders, as those of the burying beetles and so on. They grow, molt several times, and finally change into a pupa either on or in the food, or very often in a rough cell underground. From the pupa issues the fully developed winged beetle, which usually has the same food habits as the larva.

The economic status of the order *Coleoptera* is an important one. So many of the beetles are plant feeders and are such voracious eaters in both larval and adult stages that the order must be held to be one of the most destructive in the insect class. Such injurious pests as the Colorado potato-beetle, the round-headed and flat-headed appletree borers, the wire-worms (larvæ of click-beetles), the white grubs of meadows and lawns (larvæ of June-beetles), the rose-chafers, flea-beetles, bark-borers, and fruit and grain weevils are assuredly enough to give the beetles a bad name. But there are good beetles as well as bad ones. The little lady-bird beetles eat unnumbered hosts of plant-lice and scale-insects, the carrion-beetles are active scavengers, and the members of the predaceous families, as the Carabids and tiger-beetles, undoubtedly kill many noxious insects by their general insect-feeding habits. In the later chapters on injurious insects (XXX to XXXVII) many kinds of beetle pests will be described.

Order Diptera.—The *Diptera*, or two-winged flies, constitute another large order of insects, which are characterized, first of all, by their possession of but one pair of wings, those of the meso-thoracic segment, the hinder pair being transformed into two short, slender, knob-ended structures called balancers. These have a special nervous equipment, and have been shown by experiment to have some control of the equilibrium of the fly when in flight. The two wings are membranous, usually clear and supported by a few strong veins. The mouth-parts show much variety, and although no flies can bite in the sense

of the chewing and crushing biting common to beetles, grasshoppers and other insects with jaw-like mandibles, some, as the mosquito, have elongate mandibles, slender and sharp-pointed, so that they act as lacerating needles to make punctures in the flesh of animals or tissues of plants. Most flies, however, have no piercing beak, but, like the house-fly, lap up liquid food with a curious folding fleshy proboscis which is the highly modified labium or under lip. They feed on flower nectar or any exposed sweetish liquid, or on the juices of decaying animal or plant substances.

FIG. 81.—Horse-fly, *Tabanus punctifer*. (About $1\frac{1}{2}$ natural size.)

All the *Diptera* have a complete metamorphosis, the young hatching from the eggs as footless and even headless larvæ (maggots, grubs), usually soft and white, and in many cases taking food osmotically through the skin. Larvæ of different kinds of flies live under a great variety of conditions; some in water, some in the soft tissue of living plants or decaying fungi, some in the flesh of live animals or in carrion, some underground, feeding on plant roots.

The pupæ of the more specialized flies are concealed in the thickened and darkened last larval molt, the whole puparium or chrysalid looking much like an elliptical brown seed. In some

of the flies, however, as in the mosquito and other midges, the pupal stage is an active one although no food is taken during it. The life history is usually rapid so that generation after generation succeeds one another quickly. Thus it may be true, as an old proverb says, that a single pair of flesh-flies (and their progeny) will consume the carcass of an ox more rapidly than a lion.

About 50,000 species of *Diptera* are known, of which about 7000 occur in North America. The order includes the familiar house-flies, flesh-flies, and blue-bottles of the dwelling and stables; the horse-flies and green-heads that make summer life sometimes a burden for horses and cattle; the buzzing flower- and bee-flies of the garden; the beautiful little pomace-flies with their brilliant colors and mottled wings, that swarm about the cider press and fallen and fermented fruit; the bot-flies, those disgusting pests of horses, cattle, rabbits, rats, etc.; the fierce robber-flies that prey on other insects, including their own fly cousins; the midges that gather in dancing swarms over pastures and streams; the black-flies and punkies, vexers of trout fishers and campers, and worst of all, the cosmopolitan mosquitoes, probably the most serious insect enemies of mankind. A number of the specially injurious kinds of flies are described in Chapters XXIX to XXXVII.

Order Siphonaptera.—The fleas are blood-sucking parasites of birds and mammals which were long classified as a family (*Pulicidæ*) of the *Diptera*, being looked on as wingless and otherwise degenerate flies. They are now, however, given the rank of an independent order. Nearly two hundred species of fleas are known in the world, of which about fifty occur in North America. Only a few species have been found on birds, the others on mammals, both domesticated and wild.

The fleas are all wingless and have the body greatly flattened laterally. The mouth-parts are composed of several sharp, strong, piercing stylets and a pair of thicker grooved parts which can be held together to form a sucking tube. While the adults are more or less familiar the young are rarely seen. The larvæ are small, slender, white, footless, worm-like grubs which lie hidden in cracks and crevices and live on dry organic detritus.

They are especially common in dirty dwellings and in cat and dog houses. With the common cat- and dog-flea the larval life lasts only one or two weeks. When full grown the larva usually spins a thin silken cocoon within which it pupates. The adult flea issues in a few days after pupation. In a few species, as the "chigoe" or "jigger" flea of the tropics, the adults burrow into the skin of the host, lay eggs there and the young may pass their development in a sort of tumor caused by the burrowing adult. The hen-flea of the southern States has the same habit of development. The rat-fleas have been

FIG. 82.—Human-flea, *Pulex irritans;* male.

proved to disseminate the germs of plague among rats (see Chapter XXIX). The commonest fleas affecting man are the human-flea, *Pulex irritans*, and the cat- and dog-flea, *Ctenocephalus canis*. The best way to fight them is to keep rooms and the places where cats and dogs sleep thoroughly clean. Flea larvæ will not develop successfully in places where they are often disturbed, hence much sweeping and scrubbing will keep them down. The adult fleas are very resistant to insecticides.

Order Lepidoptera.—*Lepidoptera*, or moths and butterflies, are the insects most favored of collectors and nature lovers. The beautiful color patterns, the graceful flight and dainty flower-haunting habits and the interesting metamorphosis during their development make them very attractive, while the comparative ease with which the various species may be determined and the large number of popular as well as more technical books about them make the moths and butterflies, among all the insects, most collected and studied.

About 7000 species are known in North America, and except for a few kinds with wingless females and a few other clear-winged kinds which have a superficial likeness to wasps and bees, all the species may be readily recognized as moths or butterflies by the complete coating of tiny scales on the four wings both above and below. It is on these scales that the colors and patterns of the moths and butterflies depend. The scales are very small, varying from 1/350 to 1/30 of an inch in length and from the thickness of a fine hair to 1/60 of an inch in breadth. They are arranged in more or less regular rows, which overlap each other so that a shingle-like covering over the wing is produced. On a large butterfly the total number of scales on all the wings may number more than a million. Each scale is really a tiny flattened membranous sac with a short stem which is held in a little pit or pocket in the wing membrane. All the scales are finely and regularly striated from base to tip, and most of them contain a number of small pigment granules. The colors are produced both by the pigment and by the complicated reflections caused by the striated and laminated structure of the scales. On the latter condition depend the irridescent and metallic colors, such as the changing blues and greens, while on the presence of the pigment depend the fixed brown, reddish and yellow colors. The wings themselves are large and membranous and supported by a few strong veins. The fore wings are longer and narrower in proportion to their length than the hind wings, this condition being particularly emphasized among the swift-flying species, such as the sphinx-moths.

The mouth-parts of all the *Lepidoptera*, except a few

primitive species of moths, are extraordinarily modified so as to form a long, slender, flexible, sucking tube, by means of which flower nectar and water can be drunk. This tube is made of the two elongated maxillæ, grooved on their inner faces and held, even locked, together to form a perfect tube. Upper lip, mandibles, and under lip are either wholly wanting or reduced to mere rudiments. Thus no adult moth nor butterfly can seriously injure any plant or animal; but strongly contrasted to this innocuousness of the adults are the serious capacities for mischief of the larval or caterpillar stage.

From the eggs, which are almost always deposited on the proper special food plant, hatch the well-known worm-like larvæ or caterpillars which are provided with strong biting mouth-parts. They proceed at once to the serious business of voracious eating. The young caterpillar may eat many times its weight of leaf tissue in a single day, and where the caterpillars are abundant they may quickly defoliate whole shrubs and trees. The caterpillars are provided with three pairs of jointed thoracic legs and five pairs of fleshy unjointed abdominal legs, and can migrate freely from plant to plant, thus increasing their capacity for harm. When they are full grown they usually burrow into the ground, spin a silken cocoon, or seek some hiding place in which to pupate. The pupa is enclosed in a thick, horny, chitinized cuticle, and is wholly inactive and takes no food. When the radical changes of the breaking down of the larval organs and the building of the new organs of the adult are completed, the cuticle breaks and the winged imago emerges.

The food habits of the caterpillars make many of them serious pests of growing crops. Most are leaf eaters, and all are voracious feeders, so that an abundance of cut-worms or army-worms or tomato-worms always means hard times for their favorite food plants. Some kinds do not eat leaves but attack fruits, as that dire apple pest, the codling-moth larva; while still others are content with dry organic substances, as the larvæ of clothes-moths, meal-moths and the like. The sole material compensation which the *Lepidoptera* make for their disastrous toll on all green things is the gift of silk made by the

moth species known as the mulberry or Chinese silk-worm. This thoroughly domesticated and industrious species produces each year over $100,000,000 worth of fine silk. It can be reared with perfect success in this country and made to produce large cocoons of an admirable quality of silk, but the cost of the labor necessary to caring for the larvæ through their long

FIG. 83.—Silk-worms, larvæ of the moth *Bombyx mori*. (About ⅓ natural size.)

growing period is so much higher in America than in Italy, or France, or the Orient, that silk cannot be produced here under present conditions to commercial advantage. The method of rearing silk-worms is, briefly, as follows.

The heavy, creamy white moths take no food, and most of them cannot fly despite their possession of well-developed wings, so degenerate are the flight muscles from generations

of disuse. The eggs, about 300, are laid by the female on any bit of cloth or paper provided for her by the silk-worm growers. In the annual race of silk-worms, *i.e.*, the one which produces but one generation a year, the eggs go through the winter and hatch in the following spring at the time the mulberry trees begin leafing out. Other varieties produce two (bivoltins), three (trivoltins), and even five or six (multivoltins), generations a year. The larvæ, or "silk-worms," must be abundantly fed with either mulberry or osage orange leaves from which all rain or dew drops must be wiped off. When very young they are fed but two or three times a day, but later in their life must have seven or eight daily meals. They grow rapidly, and in most races are dull slaty white in color with a few indistinct darker markings. They are very sluggish in habit and can easily be kept in shallow open trays, which should be kept well aired and cleaned. The worms molt every nine or ten days, ceasing to feed for a day before each molting during the forty-five days of larval life. At the end of this time each worm spins a dense white or golden or pale greenish silken cocoon which is, to man, the silk-worm's *raison d'etre*, but which is primarily the protecting cover for the defenseless pupa.

In spinning this cocoon the silken thread, which issues from the mouth and is produced by the hardening of a viscous fluid secreted by a pair of long silk glands stretching far back in the body, is at first attached irregularly to near-by objects, so that a sort of loose net or web is made; then the spinning becomes more regular, and by the end of three days the thick, firm, symmetrical, closed cocoon, composed of a single continuous silken thread, averaging over 1000 feet long, is completed. Silk growers provide a loose network of branches or wicker on which the silk-worms spin their cocoons. Inside the cocoon the larva pupates, and if undisturbed the chrysalid gives up its damp and crumpled moth after from twelve to fourteen days or longer. A fluid secreted by the moth softens one end of the cocoon so that the delicate creature can force its way out. But this is the happy fate of only those moths which the grower allows to issue to lay eggs for the next year's crop. To produce good silk the grower must save the

cocoon from injury by the moth, so he kills his thousands of pupæ by dropping the cocoons into boiling water or by putting them into a hot oven. Then, after cleaning away the loose fluffy silk of the outside, he finds the beginning of the long thread which makes the cocoon, and with a clever little reeling machine he unwinds, unbroken, its hundreds of

FIG. 84.—The luna-moth, or pale empress of the night, *Tropæa luna*. (About $\frac{3}{4}$ natural size.)

feet of merchantable silk floss. Or the cocoons are taken to a central establishment where the pupæ are killed and the silk wound and made into large skeins ready to go to the cloth-making mills.

The order *Lepidoptera* is divided into three principal sub-orders, namely, the *Rhopalocera*, or butterflies, which are day

fliers, and which have their antennæ slender and thread-like with the tip thickened so as to form a small spindle-shaped club; the *Hesperina*, or skippers, which are also day fliers and which have the antennæ slender and with slightly expanded or hooked tip; and the *Heterocera*, or moths, most of which are night fliers, and which have their antennæ variously formed, either entirely thread-like or with some of the segments provided with many long hairs arranged so as to make the antennæ look like a flat brush. The *Heterocera* include by far the greater number of species of *Lepidoptera*, and many of the more obscurely colored ones are rarely seen. They vary in size from the small clothes-moths and leaf-miners to the great Cecropias and Luna. Colored pictures of most of the more common kinds of moths and butterflies can be found in nature books, and the different species can readily be determined by referring to these pictures. A number of the species with injurious caterpillars are described in Chapters XXX to XXXVII.

Order Hymenoptera.—The *Hymenoptera* are a large order, which includes, besides the popularly known ants, bees and wasps, many less familiar insects showing much variety in appearance and habit, 7500 species being found in this country alone. Many of these are parasites, spending their larval life within the bodies of other insects, feeding on their tissues and finally destroying them. Because of the great importance of these parasites in keeping noxious insects in check, and because of the gifts from the honey-bee and the innocuous character of most of the other members of the order, the *Hymenoptera* may be looked on as the chief beneficial order of insects.

Few generalizations can be made that will apply to all members of the order although there is no question concerning the true relationship of all the kinds of insects included in it. The name of the order is derived from the clear membranous condition of the two pairs of wings (*hymēn*, membrane, *ptera*, wings). The front wings are larger than the hind ones and all are provided with comparatively few branched veins. The workers of all the ant species are wingless as are also the

females of certain wasps. In many *Hymenoptera* the front margin of the hind wings bears a series of small recurved hooks which, when the wings are outspread, fit over a ridge on the hind margin of the fore wing thus fastening the two wings firmly together. The mouth-parts are variously modified, but usually are fitted for both biting and lapping. This is arranged for by having the maxillæ and labium more or less elongated and forming a sort of proboscis for taking up liquids, while the mandibles always retain their short, strong, jaw-like character. The females throughout the order are provided either with a saw-like or boring or pricking egg-layer (*ovipositor*), or with the same parts modified to be a sting.

In the development of all *Hymenoptera* the metamorphosis is complete, and the larvæ are, more than in any other order, helpless and dependent for their food and safety on the special provision or care of the parents. The parasitic species lay their eggs either on or in the body of the insect which is to serve as food for the larvæ, while the gall-making kinds lay their eggs in the plant tissue on which their larvæ feed. With most of the solitary wasps and bees, food is stored up in the cell in which the egg is deposited, so that the larvæ on hatching will find it ready. With the social wasps and bees and all the ants, the workers bring food to the young during their whole larval life.

The *Hymenoptera* may be roughly divided into a few important groups. First, the saw-flies (family *Tenthredinidæ*) whose larvæ, soft-bodied, naked, caterpillar-like creatures, usually with six to eight pairs of abdominal legs besides the three pairs of thoracic legs, are called slugs. Common kinds are the current-slug, rose-slug, larch-slug and others, which do considerable damage by eating away the soft tissues leaving only the veins, thus making "skeletons" of the leaves of their food plants. The saw-flies compose a large family, 600 species being known in this country, but the adults are rarely seen by the general observer.

Second, the great group of parasites comprising several families (*Ichneumonidæ*, *Braconidæ*, *Chalcididæ*, *Proctotrypidæ*, and others), and including species varying in size from the

smallest insects known to others two inches or more in length. Some of these minute parasites lay their eggs within the eggs of other insects, and their larvæ live their whole lives in the contents of these host eggs, but most Hymenopterous parasites deposit their eggs on the skin of the larvæ or nymphs of other insects, especially on caterpillars. The parasite larvæ, on hatching, bore their way through the skin into the host body and remain there, feeding on the blood lymph and perhaps on other body tissues. The host dies, but usually not until the parasites have completed their larval life and have changed to pupæ either within the host's body, or have issued from it and pupated outside. Parasitized caterpillars are often able to pupate, but from their pupa there issues, not a moth or butterfly, but many of the little four-winged parasites. These fly freely about, mate, and then deposit their eggs on the body of other hosts.

FIG. 85.—Ichneumon fly, *Pimpla conquisitor*, laying egg in cocoon of American tent-caterpillar moth. (About natural size; after Fiske.)

A few members of this group are not parasites but gall-makers. Among these an important kind is the curious small fig-wasp (*Blastophaga*) by which the Smyrna figs are cross-pollinated and made to set seed and thus to become especially palatable. The fig-wasp has been introduced from Asia Minor into California, and has greatly added to the value of California figs.

Third, the family *Cynipidæ* or gall-flies, some of which are parasites, but most of which thrust their eggs, by means of a sharp ovipositor, into the leaves or green stems of oaks, roses and a few other plants, so that the hatching larvæ find themselves surrounded by rich plant food. The presence of the larva stimulates the plant to a vigorous production of new tissue about it, which takes on the form of a gall of definite shape. These galls are different for different species of gall-flies, and for different species of plants, and present a host of curious shapes. Some look like tiny seeds or papillæ on the

leaf or stem, while others, as the giant oak-gall of California, are as large as one's fist. The gall-fly larvæ lie in the middle of the galls feeding on the abundant plant juice and pupating there in the autumn when the active plant growth ceases. The gall-flies issue in the following spring, biting their way out of the gall by means of their stout jaws.

The fourth, fifth and sixth groups of *Hymenoptera* are the wasps, bees and ants. They are treated in the following chapter.

CHAPTER XVIII

INSECTS (Continued): WASPS, ANTS, THE HONEY-BEE AND OTHER BEES

Wasps.—The wasps are divided into two groups, viz., the solitary or digger wasps (superfamily *Sphecina*), and the social wasps (super-family *Vespina*). The *Sphecina*, as represented in North America, include a dozen or more families, while the *Vespina* include but three, but these latter wasps, or a few of them, the hornets and yellow-jackets, are more often seen and much better known popularly than the solitary wasps. Among the solitary bees each female makes a simple nest, usually a short burrow in the ground or in a plant stem (in the case of a

FIG. 86.—Digger-wasp, *Ammophila*, putting inch-worm into nest-burrow. (From life; natural size.)

few parasitic kinds the wasp makes no special nest at all), lays one or more eggs in it, stores it with food for the hatching larvæ, and closes it up. This food is usually other insects or spiders stung to death or, more commonly, stung in such a way as not to kill but paralyze the prey. When the wasp larvæ hatch they find their food all ready for them, devour it slowly as they grow, pupate in the nest burrow, and finally issue as full fledged wasps.

The social wasps live, as is well known, in large communities composed of an active egg-laying female or queen, a few males

or drones, and many infertile females, or workers. A small nest is made in the spring out of chewed old wood mixed with saliva so as to form "wasp-paper," by a queen that has mated in the autumn before and passed the winter solitarily in hiding. In this little "queen nest" she lays a few eggs, brings food to the hatching larvæ until they change to pupæ in their cells, and then awaits their issuance. They issue as workers, and immediately enlarge the nest, making more paper combs and cells, in which the queen lays more eggs. The workers bring food, which is killed and masticated insects, and care for the young, which develop into more workers. Thus the community, or really family, grows through the summer, till it may contain many hundred individuals. In the late summer males and fertile females are produced, and then with the oncoming of winter the workers and males and many of the females die, leaving a few mated females to pass the winter and begin new colonies in the spring. Thus the social wasp communities break down and are rebuilt annually.

FIG. 87.—Two workers of the yellow-jacket, *Vespa* sp. (From life; natural size.)

Bees.—This is also the case with the communities of bumble bees, which are the simplest kind of social bees. There are among the bees solitary kinds also, with the same general manner of life of the solitary wasps, except that the food collected and stored for the young is never killed or paralyzed insects but always flower nectar and pollen mixed. This is also the kind of food brought by the bumble-bees for their larvæ.

Among the bees there is however another and more specialized type of social kind. This type is represented in America by a single species, the honey-bee or hive-bee, *Apis mellifica*, which is not a native insect but one introduced long ago from Europe. With this bee the community does not break down annually but persists, under favorable conditions, indefinitely.

The hive-bee has long been a domesticated species of animal, and several different varieties or races of it have been created by artificial selection, the more familiar ones being the German or black race, the Italian or amber race, and Carniolan or striped race. As the life of the honey-bee is not only one of the most interesting of all animal lives, but is one which the economic zoologist needs especially to know, we give in the following pages a rather detailed account of the natural history of the honey-bee, mostly taken from Chapter XV of "American Insects," by the senior author.

FIG. 88.—Bumble-bee at clover blossom. (From life; natural size.)

The Honey-bee.—A community of the hive-bee, which may live, of course, not in a hive at all, but in a hollow tree, as undoubtedly was the habit of the species in wild state (the "bee-trees" of America, however, are inhabited by bee colonies which have swarmed away from domesticated ones and are only wild by virtue of escaping from the slave-yards of their human masters), consists normally of about 10,000 (winter) to 50,000 (summer) individuals, of which one is a fertile female, the queen; a few score to several hundred are males, the drones; and the rest are infertile females, the workers. These three kinds of individuals are readily distinguishable by structural characters. The queen has a slender abdomen one-half longer than that of a worker, she has no wax-plates on the underside of the abdominal segments, and no transverse series of comb-like hairs, the planta, on the underside of the broad first tarsal segment of the hind feet, and no pollen-basket on the outer surface of the hind tibia. The drones, males, have a heavy broad body excessively hairy on the thorax, and lack pollen-basket, planta, wax-plates, and other special structures of the workers. The workers are smaller than queen or drones, and

possess certain special structures or body modifications to enable them to perform certain special functions connected with their performance of the various industries characteristic of the species. These special structures will be described in some detail later when the various special industries are particularly considered. In internal organization the workers differ from the queen in having the ovaries rudimentary, so that only in exceptional cases can workers produce fertile eggs.

In functions the three castes differ as they do in the social wasps and the bumble-bees, only more constantly; that is, the queen lays the eggs, never, as with the bumble-bees and social wasps, doing any food-gathering or nest-building; the males act simply as consorts for the queen, which means that only one of every thousand, perhaps, performs any necessary function at all in the communal economy; the workers build brood- and food-cells, gather, prepare and store food, feed and otherwise care for the young, repair, clean, ventilate, and warm the hive, guard the entrance and repel invaders, feed the queen, control the production of new queens, and, with the aid of a queen, distribute the species, founding new communities, by swarming.

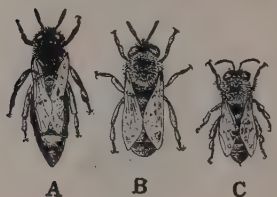


FIG. 89.—Honey-bee, *Apis mellifica*. *a*, Queen; *b*, drone; *c*, worker. (About natural size.)

The life history of a community is as follows: A "swarm" consisting of a queen and a number of workers (from two to twenty thousand or more), issues from a community nest and finds, through the efforts of a few of the workers, a place for a new nest. This is some sheltered hollow place, usually, through the intervention of the bee-keeper, another hive. Taking possession of this new nesting-place, the workers immediately begin to secrete wax and to build "comb," *i.e.*, double-tiered layers of waxen cells, usually as "curtains" or plates hanging down from the ceiling of the nest. The bee-keepers supply artificially made "foundations" or beginnings of these curtains

in vertical frames set parallel and lengthwise of the hive, so that the combs will be built symmetrically and conveniently for the bee-keeper's handling. In many of these cells the queen, which has received the fertilizing sperm-cells from a male during a mating flight high in the air, lays fertilized eggs, one at the bottom of each cell. In other cells, pollen and nectar brought by workers are stored for food. In three days the eggs hatch, the tiny larvæ being footless, white, soft-bodied helpless grubs. They are fed at first exclusively with "bee-jelly," a highly nutritious, "pre-digested" substance elaborated in the bodies of the nurse workers and regurgitated by them into the mouths of the larvæ. After a couple of days of feeding with this substance, the larvæ are fed, in addition to bee-jelly, pollen and honey taken by the nurse from the cells stored with these food-substances. After three days of this mixed feeding, the larvæ having grown so as to fill half or two-thirds of the cell, lying curled in it, a small mass of mixed pollen and honey is put into each cell, which is then capped, *i.e.*, sealed over with a thin layer of wax. The larva feeds itself for a day or two longer on the "bee-bread" and then pupates in the cell. The quiescent non-feeding pupal stage lasts for thirteen days, when the fully developed bee issues from the thin pupal cuticle, gnaws away the wax cap and emerges from the cell. For from ten days to two weeks the bee does not leave the hive; it busies itself with indoor work, particularly nurse work, the feeding and care of the young. Then it takes its place with the fully competent bees, makes foraging expeditions or undertakes capably any other of the varied industries of the worker caste.

After numerous workers have been added to the community, egg-laying by the queen going on constantly, so that the young come to maturity, not in broods, but consecutively, day after day, certain hexagonal cells of plainly larger diameter are made by the comb-building workers, and in these the queen lays unfertilized eggs. This extraordinary capacity for producing either fertilized or unfertilized eggs, as demanded, depends upon the queen's control of the male fertilizing cells held in the spermatheca. This reservoir of fertilizing cells can be kept

open as eggs pass down the oviduct and by it on their way out of the body, thus allowing the spermatozoids to swim out, penetrate (through the micropyle in the egg-envelopes) and fertilize the eggs, or it may be kept closed, preventing the issuance of the spermatozoids and, consequently, fertilization. From the unfertilized eggs laid in the larger cells hatch larvæ which are fed and cared for in the same way as the worker larvæ, but which require six days for full growth, the pupal stage lasting fifteen days. When finally the fully developed bees issue from these cells it will be found that all are males (drones). This parthenogenetic production of drones, discovered about 1840 by Dzierzon, and long accepted as proved, was recently questioned by Dickel and one or two other naturalists and was therefore reinvestigated by Petrunkewitsch and others, with the result of confirming, on new evidence, and by new methods of investigation, the declarations of the discoverer of the fact.

If, now, the bee community has increased so largely in numbers that its quarters begin to be insufficient for further expansion, excited groups of workers will be seen tearing down certain cells and replacing them by a new giant cell which is usually built up around one of the fertilized eggs laid in a small hexagonal cell. The egg hatches before the cell is finished, and the larva lies in the large open cavity of the growing cell, on which numerous nurses are in constant attendance. Often several of these unusual giant cells may be built at one time. The larva which hatches from the fertilized egg in one of these cells is fed the nutritious bee-jelly through all of its life, little or no pollen or honey being given it. When the larva is five days old a quantity of the milky semi-fluid jelly is put into the cell, which is then capped, the opening being at the bottom of the hanging, nut-shaped cell, and in only seven days more the fully developed bee issues. This bee is a queen. Very rarely a worker and not a queen issues from a queen-cell. That is, a larva hatching from a fertilized egg laid by the queen in a small hexagonal cell, if fed bee-jelly for two or three days and then pollen and honey, will develop into a worker; that larva from the same egg if fed bee-jelly all its life, and

reared in a large roomy cell, will develop into a queen. The differences between a queen honey-bee and a worker honey-bee, both structural and physiological, are, as already pointed out, conspicuous. The influence of a varying food-supply is something mysteriously potent, and this case of the queen bee gives great comfort to those biologists who believe that the external or extrinsic factors surrounding an animal during development have much influence in determining its outcome.

As there is by immemorial honey-bee tradition but one queen in a community at one time, when new queens issue from the great cells something has to happen. This may be one of three things; either the old and new queens battle to death, and it is believed that in such battles only does a queen bee ever use her sting, or the workers interfere and kill either the old or the new queen by "balling" her (gathering in a tight suffocating mass about her), or either old (usually old) or new queen leaves the hive with a swarm, and a new community is founded. If several new queens are to issue, the workers usually, by thickening the outside walls of one or more of the cells, compel the issuing to be successive and not simultaneous. This results in a series of royal battles, or a series of swarmings, or a combination of the two. A queen ready to issue from a cell makes a curious piping audible some yards from the hive, which is answered by a louder piping, or trumpeting, from the old queen. At these times there is great excitement in the hive, as indeed there is during all of the queen-raising season.

The swarming out, it is apparent, does not break up the old community; in fact only accident, or the successful attacks of such insidious enemies as the bee-moth, and various contagious diseases, break up the parent colony. In this respect is to be noted an important difference between the other social bees and wasps with their communities annually destroyed and refounded, and the honey-bee with its persistent one. Of course workers die and so do drones and queens. The tireless workers which hatch and labor in the spring and summer months rarely live more than six or eight weeks, while the workers born in the late autumn and remaining quietly in the shelter of the hive through the winter live for several months.

Queens live, usually, if no accident befalls, two or three years; an age of four or five years is occasionally attained. Most of the drones in each community either die naturally before winter comes or are killed by the workers. Feeble workers and larvæ and pupæ are also sometimes killed just before winter, if the food-stores which are to carry the community through the long flowerless season are for any reason not likely to prove sufficient for so large a number of individuals. In all these matters, that is, the making of queens and when, the swarming out and when, and the reduction of the community to safe winter numbers, the decision is made by the workers and not the queen. The queen is not a ruler; she is the mother, or, better, simply the egg-layer for the whole community.

The drones, we have seen, have one particular function to perform in the community life, the queen another single particular function; but the workers have numerous varied performances to achieve if the community shall live successfully. It might be expected by analogous conditions elsewhere existing in animal life, that with the division of labor in the honey-bee economy there should be a corresponding differentiation of structure or polymorphism inside the species. This polymorphism or existence of structurally different kinds of individuals occurs in bees only to the extent already pointed out; there are three kinds of individuals: the queens, with a special function, the drones with a single special function, and the workers, each capable of performing, and, for the time of the performance, doing it exclusively, any of the varied industries necessary to the community life. All worker honey-bees are alike, each possessing all the special structural specializations, as pollén-basket, wax-plates, wax-shears, trowel-like jaws, etc. which have been developed for the special performance of particular industries. In some other communal insects a differentiation or polymorphism among the workers exists; many ant species have two and even three kinds of workers, the termites have soldiers as well as workers, etc. We purpose now to describe briefly each of the principal special industries achieved by the workers, at the same time describing the structural specialization connected with each of these industries.

The wax produced by the workers is a secretion which issues as a liquid, soon hardening, from pairs of thin five-sided plates, one pair on the ventral surface of each of the last four abdominal segments. It is secreted by modified cells of the skin, lying under the chitinized cuticle of the plates, and oozes out through fine pores in the plates. To produce it certain workers eat a large amount of honey, then, massing together, form a curtain or festoon hanging down from the ceiling of the hive or frame, and increase the temperature of their bodies by some strong internal exertion; after the lapse of several hours, sometimes indeed of two or three days, fine, thin, glistening, nearly transparent scales of wax appear on the "wax-plates." These wax-scales continue to increase in area and soon project beyond the margin of the segment, when they either fall off or are plucked off by the wax-producing worker. They are then taken in the mouth, sometimes chewed and mixed with some saliva, and carried to the seat of the comb-building operation. Here the wax is pressed against the frame roof (or artificial foundation) and by means of the trowel-like mandibles moulded into the familiar hexagonal cells; each comb being composed of a double layer of these cells, a common partition serving as base or bottom of each tier. Although most bee books speak rather glibly of the comb-building operations, many of its details are still undetermined. In building cells for storing honey, new wax is almost exclusively used; for brood-cells, old wax and wax mixed with pollen may be used. Any comb or part of a comb not needed is torn down and the wax used to build other comb or to cap cells.

FIG. 90.—Ventral view of abdomen of honey-bee worker, showing wax plates. (About 3 times natural size.)

The seeking and collection of pollen and honey is not undertaken by a bee until from ten to fifteen days after its emergence from the pupal cuticle, these first days being spent in the hive at nurse or other indoor work. Then short orienting flights begin to be made, and soon the long-distance flights (a mile or

more sometimes), which are often necessary for successful foraging, are undertaken. The pollen is taken up or brushed off from the ripe anthers of the flowers with the mouth-parts, fore legs or ventral body-wall, the pollen-grains being readily entangled in the numerous branching hairs, and then, by clever manipulation of the fore, middle, and hind legs aided by special pollen brushes (plantæ) on the inner side of the first tarsal segments of the hind feet, transferred and packed into the pollen-baskets, one on the outer face of each hind tibia. A forager loaded with pollen returns to the hive, and, seeking an empty cell near the brood-cells, stands over it and with her hind legs partly in it, thrusts off the two masses with the aid of the middle legs (the spurs of the middle tibiæ being apparently often used as pries). This pollen is tamped down in the cell by inside workers and receives no further manipulation.

The "honey" which is collected by the foragers is not yet bee-honey, but is nectar of flowers, too watery and too likely not to "keep" to be stored in the cells without further treatment. It is sucked and lapped up by the complicated elongate flexible mouth-proboscis, swallowed into the fore-stomach or honey-sac, and carried in this to the hive. Bees have been seen to exude drops of water on their return flight when honey-laden, and it is possible that it comes from the nectar in the honey-stomach. At any rate some 10 or 12 per cent. of the water content of the nectar has to be evaporated before this nectar becomes honey. When the foraging worker with honey-sac full returns to the hive it regurgitates its nectar either into the mouth of another bee or into a clean (new wax) cell, usually near the margin of the comb. At the bottom of the honey-sac is the so-called stomach-mouth, a little pea-like protuberance with two cross-slits, making four lips. These lips can be opened or closed voluntarily; if the bee drinking nectar wishes to bring it back to the hive to store it, she keeps them closed, thus making a sac of the honey-stomach, open only through the mouth; whenever she wishes to feed herself she opens them, thus allowing the honey or pollen to pass on into the true or digesting stomach. This arrangement also

permits of the regurgitation of the bee-jelly or bee-milk (fed the larvæ by the nurse workers), which is believed to be prepared in the true stomach, pressed past the lips forward into the honey-stomach and on through the esophagus into the mouth.

When the nectar is put into the honey-cells it has still to have much water evaporated from it. To accomplish this an effective system of ventilation is set up in the hive, so that air-currents pass constantly over the open nectar-containing cells; moreover, by the very vigor of this activity on the part of the bees the temperature of their bodies is raised; by radiation of heat from the bodies the temperature in the hive is sensibly increased, and the currents of warm air soon carry off the excess water. To make the honey "keep," that is, to make it antiseptic, formic acid is added to it, probably from glands in the head whose secretions distinctly show its presence. It is just possible that the formic acid is supplied by the poison-sacs, the poison introduced by the bee's sting being largely composed of formic acid. But it is much more probable that at the time of the regurgitation of the nectar from the honey-stomach through the mouth the formic-acid secretions from the head-glands are mixed with it.

Nectar for honey-making is obtained by bees from a great many different plants, but that from some makes honey better, to our taste, than that from others. Among the most important producers of the best honey in the east and north are white clover, basswood, buckwheat, and the fruit trees and small fruits; in the middle states are the tulip tree, sorrel-tree, sweet clover, and alfalfa; in the south are the mangrove, cabbage- and saw-palmettos, orange trees and sorrel-tree; while in the west are alfalfa and white sage.

Besides pollen and nectar, two other substances are collected and brought to the hive by the foraging workers. At some seasons of the year when many larvæ are being reared, and the supply of water derived by condensation of the moisture in the warm hive atmosphere as this air strikes the cooler hive-walls is insufficient, the workers drink up dew from leaves, or water from puddles, which they hold in the honey-sac and bring

to the hive, regurgitating it into the thirsty larval mouths. For the filling in of crevices, the stopping up of holes, the fastening together of loose parts, etc., the bees use a substance called propolis, which is made of the resinous exudations of various plants. This propolis is collected and packed into the pollen-baskets as pollen is and brought in by the foragers. Some of our bees, needing propolis, discovered a house just in course of painting, and made a gallant though hopeless struggle to bring in all the fresh paint as fast as it was put on by the painters! Propolis is not packed in cells, but is used as soon as brought in, the trowel mandibles being the instruments used in putting and moulding it in the needed place.

Of the indoor work there is much besides those industries already referred to, namely, wax-making, comb-building, honey-making, crevice-chinking. Because the queen and nurses (bees less than two weeks old) do not leave the hive, their excreta are voided within doors; there are also bits of old, dirty wax, occasional dead bees, and various other waste substances constantly accumulating in the hive. Or, rather, this detritus would accumulate if the workers were not always keenly careful to carry out all such stuff; the hive is constantly being cleaned, and is on any day in the week a model of good housekeeping.

Besides keeping the hive clean the workers must keep it ventilated, that is, clean of atmosphere as well as clean of floor and wall. This is done by setting up air-currents through the hive which carry out constantly the vitiated air and thus compel fresh air to enter. Always near the exit and scattered through the hive, especially along its floor, may be seen bees standing with head down and body diagonally up and wings steadily vibrating with great rapidity. These are the ventilating agents, and they have an exhausting and tedious work.

About the entrance may be also always seen bees which seem neither to be leaving the hive nor entering it, but which move about constantly and meet and touch antennæ with all incomers. These are the warders of the gate. There are never wanting enemies of the industrious, well-stocked honey-bee

community, whose entrance into the hive must be vigorously guarded against. Yellow-jackets hover tentatively around the opening; they are arrant robbers and are ready to take any chance to get at the full honey-cells. But more dangerous, because of the habit of attacking *en masse*, are honey-bees of other hives. Not infrequently a desperate foray by hundreds

FIG. 91.—A small observation hive in which the honey-comb has been destroyed by larvæ of the bee moth, *Galleria mellonella*. (Greatly reduced.)

of other bees will be made into a hive, especially a weak one, and a pitched battle will occur in and about the entrance and inside the hive itself, resulting in the death of hundreds, even thousands of bees. More insidious and even more dangerous are the stealthy invasions of a small dusty-winged moth, the "large" bee-moth, *Galleria mellonella*, or the "small" bee-moth,

Achroia grisella, which, slipping in at night unobserved, lay their eggs in cracks; the larvæ which hatch from the eggs feed on the wax of the combs, and as they spin a silken net over them wherever they go, the presence of many such larvæ works great injury both in the actual destruction of comb and in the felting and cobwebbing of the interior of the hive with the tough silken netting. Other still more insidious enemies there are, as the minute bee-lice, *Braula*, which attach themselves to the bees and suck out their body juices, and the invisible bacterial germs of foul-brood and other characteristic bee diseases. But all these are beyond the sensitiveness of the guards to recognize, and for the successful fighting of them the aid of the bee-keeper is necessary.

The feeding and care of the young bees, the larvæ, have already been partly described in the account of the life history of the different kinds of individuals in the community, and cannot be further referred to in this brief history of the honey-bees' domestic economy. Of course only the more conspicuous features in this economy have been described at all; a host of interesting details cannot even be mentioned. But enough has been said, surely, to indicate the fascinating field of observation afforded by a honey-bee community. If such a community be kept in an observation-hive and this hive be placed conveniently near the house, or, better, *inside one's room*, it will prove a never-failing source of interest and pleasure.

Perhaps it had better be explained how an observation-hive can be kept in one's room without interfering with coincident human occupancy. The observation-hive, in the first place, may be simply an outdoor hive into each side of which a large pane of glass has been let, with swinging outer wooden doors, one on each side, which, when shut, keep the hive in normal darkness, but opened, allow "observing" to go on. In addition to the side glasses a loose sheet of glass is inserted just under the ordinary "honey-board" or removable top of the hive. Or the observation-hive may be a special narrow, two-frame hive, with both sides wholly composed of glass held in the narrow wooden frame which forms the ends and the top and bottom of the hive. A black cloth jacket should be kept

on the hive when "observing" is not going on. In such a hive, which will obviously hold but a small community (one of not over 10,000 individuals) any single bee can be kept continuously under observation, as there are no side-by-side frames between which it can crawl and thus be hidden from view. To keep either of such hives in the house it is only necessary to substitute for a pane of glass in a window a thin wooden pane in which is cut a narrow horizontal opening, the size of the regular hive-opening (if the latter is too broad it can be

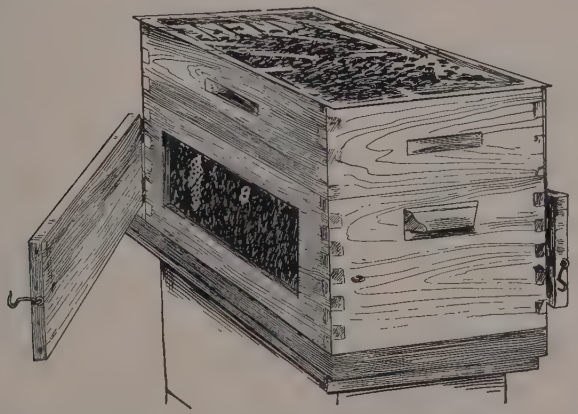


FIG. 92.—An ordinary bee-hive made into an observation hive by inserting glass panes in sides and putting a glass sheet under the wooden cover.

closed for a few inches at each end). Or a narrow broad strip of the full width of the window can be inserted so that the lower sash of the window, when closed, will rest upon this strip. In the strip cut a narrow opening of the width, or less, of the hive opening. Set the observation-hive on a table or shelf against the window so that the hive-opening corresponds with that in the window pane or window-strip. Or, better, place it six or seven inches from the window and connect hive and window-opening by a shallow broad tunnel of wooden

bottom and sides but glass top. Over the glass top of this tunnel lay a sheet of black cardboard, which will keep the tunnel dark normally, but which can be simply lifted off whenever it is desired to see what is going on at the entrance. Here can be seen the departure of the foragers and their arrival with pollen, propolis, or honey, the alertness of the guards, the repelling of robbers and enemies, the killing of drones, the ventilating etc., etc. Through the glass sides of the hive itself can be seen all the varied indoor businesses in their very undertaking; the life history of each kind of individual can be followed in detail; the wax-making and comb-building, the storing of the food-cells, the feeding of the young by the nurses, the excitements, the joys, and the discouragements, the whole course of life in this microcosm.

Practical bee-keeping is based first of all on a sound knowledge of the natural history of the honey-bee, and second on an acquaintance with the methods and tools used in handling hives and honey. To the acquirement of the first of these requirements we have just tried to guide the student. For the second we must refer him to some one of the many book guides for such work. Anna B. Comstock's "How to Keep Bees" is a good small book; Root's "A, B, C and X, Y, Z of Bee Culture" is a good larger one.

Cross-pollination of Flowers by Bees and Other Insects.—A means by which insects indirectly render a great economic service to man is by their cross-pollination of flowers. The nectar of flowers is a favorite food with many insects; all the moths and butterflies, all the bees and many kinds of flies are nectar-drinkers. Flower-pollen, too, is food for other hosts of insects, as well as for many of those which take nectar. The hundreds of bee kinds are the most familiar and conspicuous of the pollen-eaters, but many little beetles and some other obscure small insects feed largely on the rich pollen-grains. But the flowers do not provide nectar and pollen to these hosts of insect guests without demanding and receiving a payment which fully requites their apparent hospitality. This payment is the cross-pollination by the insects of the nectar-providing flowers. The agency of insects in this matter

has long been recognized, and some orchard growers keep hives of bees in or near their orchards to ensure the advantage of cross-pollination to their trees.

Cross-pollination is simply the bringing of pollen from one plant individual to the flowers of another individual of the same species. Self-pollination is the getting of pollen from the stamens of one flower on to the stigma of the same flower. The advantage of cross-pollination, as first experimentally proved by Darwin, and since then confirmed by other experimenters and, without scientific intention but none the less effectively, by hosts of economic plant-breeders (horticulturists, florists, etc.), lies in the fact that the seeds produced when the ovules of one plant are fertilized by the sperm-cells (in the pollen) of another, develop plant individuals of markedly stronger growth (shown in size of plant and its fruits, in number of seeds, etc.), than seeds produced by the fertilization of ovules by sperm-cells of the same plant. For the sake of insuring this cross-pollination the flowers of many plants are highly specialized. This specialization follows two general lines: One includes means of preventing self-pollination such as having stamens and pistils ripen at different times, or be of such different lengths that the pollen cannot fall on the pistils in the same flower, etc. The other line includes means for attracting insects, such as color and pattern and the secretion of nectar, and means, such as shape, curious modification of flower parts, etc., to compel the visiting insects both to leave on the stigma pollen brought from other flowers and to carry away from the anthers pollen from the flower being visited. Honey bees are undoubtedly the most important of all insects concerned with cross-pollination, and perform in this way a great service to flower and orchard growers.

The Ants.—The ants constitute the fifth and last principal group of *Hymenoptera*, and for their adequate treatment a book much larger than the whole of this one would be necessary. Such a book, indeed, has been recently written by Professor W. M. Wheeler,[1] the foremost American student of ants, and

[1] Wheeler, W. M. Ants, their Structure, Development and Behavior, 1910.

it is one of the most fascinating and stimulating books of natural history ever written.

About five thousand kinds of ants are known, all of which live socially in small or large communities comprising three usually well-distinguished types of individuals, namely, fertile females, or queens, males, or drones, and sterile females, or workers. The workers are wingless, while the males and queens are winged, although the queens pull off their wings after mating. There may be a certain further amount of structural differentiation within a species in that the workers may be of two or three different types. The general appearance of ants is so characteristic that they are readily distinguished from all other insects, and their extraordinarily developed communal life is more or less familiarly known to every observer or reader. To the economic zoologist, however, ants do not present any very large importance. A few kinds of house ants can be extremely troublesome and a few garden-infesting kinds do some injury to vegetables and fruits. Their greatest damage probably is done indirectly, through their habits of protecting and caring for plant-lice (aphids), from which they obtain their favorite food of "honey-dew." All of these protected aphids are injurious to plants because they suck their sap.

The ant communities live in nests comprising a number of irregular chambers and galleries, most of the species living underground, although a considerable part of the nest may be above the normal ground surface, built up as a mound or "ant-hill" of more or less symmetry and greater or less size. This part above ground may be composed chiefly or wholly of soil brought up from below surface, or may be partly or wholly made up of bits of wood, grass and weed stems, chaff or pine-needles. The nest may be made under a stone or log, or be established in a wholly exposed place. Most ants keep their nest fairly near the surface, but a few mine deeply. Still other species tunnel out their corridors and rooms in wood—an old log or stump, dry branches, or what not—while yet others live in the stems of plants, in old plant-galls, in hollow thorns and spines; finally, a few make nests of delicate paper or tie leaves together with silken threads. Very wonderful are some of the

inter-relations between certain plants and certain ant species in tropic regions, whereby the plant seems to have developed suitable cavities for the accommodation of the ants, whose presence in turn is advantageous to the plant by the protection it affords against the ravages of certain leaf-eating insects which are repelled, or rather attacked as prey, by the ants. In many cases two ant species will live together in a compound or mixed nest, the relation between the two species being (a) simply that of two close neighbors, friendly or unfriendly; (b) that of two species having their nests with "inosculating galleries" and "their households strangely intermingled but not actually blended"; (c) that of one species, usually with workers of minute size, which lives in or near the nests of other species and preys on the larvæ or pupæ or surreptitiously consumes certain substances in the nests of their hosts—some different larger species—that is, the relation of thief and householder; (d) that of two species living in one nest but with independent households, one of these species living as a guest or inquiline at the expense of the food-stores of the other, but consorting freely with their hosts and living with them on terms of mutual toleration or even friendship; and (e) that of slave-maker and slave, a relation not at all rare and readily observed all over our country.

Inside the nest the eggs are laid by the queen or queens in large numbers, not in separate cells as with the wasps and bees, but in little piles heaped together in various rooms and sometimes moved about by the workers. The hatching larvæ, tiny, white, footless, helpless, soft-bodied grubs, are fed by the workers either a predigested food regurgitated from the mouth, or chewed fresh insects, caught and killed by the workers, or dry seeds or other vegetable matter brought into the hive and stored in the "granary" rooms. A single species may use all these different kinds of food, but for the most part the ants belonging to one species habitually use one kind of food for the young. The primitive food consists of seeds and cut-up insects. The adult ants feed on a variety of substances, both animal and vegetable, almost all, however, having a special taste for sweetish liquids, such as the secreted honey-dew of

plant-lice, scale-insects, certain small beetles and others, and the sugary sap of certain trees. The males and fertile females are fed by the workers.

Besides feeding the larvæ, the nurses have to see that the young enjoy suitable temperature and humidity of the atmosphere; this is accomplished by moving the larvæ or pupæ from room to room, farther below the surface, or even out into the warm sunshine above ground. The carrying about of ants' "eggs," which are not eggs but usually the cocooned pupæ, by the workers, is a familiar sight around any ant-nest, particularly a disturbed one. The various special industries undertaken by ants, as the attendance on and care of honey dew-secreting plant-lice, the fungus-growing in their nests, the harvesting (but not planting!) of food-seeds, the waging of wars for pillage or slave-making, the long migrations, etc., etc., are more or less familiar through much true and some inaccurate popular writing.

In any community there may live at one time several (two to thirty) queens with wings removed. In small colonies there is, however, usually but one. As already mentioned, winged ants are to be seen only at certain times in the year. When a brood of sexual individuals (males and females) is matured in the community, these winged forms issue on a sudden impulse (comparable in a way with the outwinging ecstasy of bees at swarming time) from all the openings of the nest and take wing. The air may be swarming with them, flights from neighboring nests intermingling and joining. This is the mating flight, and after it is over those ants which have escaped the bird attacks and other dangers attending this bold essay into the outer world alight or fall exhausted to the ground; the males soon die, while the females pull the wings from the body and get under cover. In the communal nest, therefore, winged ants are rarely found. The life of the workers of most ant species is conspicuously longer than that of other social insect workers; they live for from one to three or four or even five years. Lubbock has kept workers until six years old, and queens until seven. The males all die young, but both other kinds of individuals are exceptionally long-lived for insects.

There are several different ways in which a new community may be founded. A fertilized queen may begin alone the establishment of a new community by building a little nest, laying a few eggs, caring for the hatching larvæ herself, and thus raising by her unaided exertions a small brood of neuter workers which are always normally undersized, probably from insufficient nourishment. This mode of community founding is just like that obtaining among the social wasps and the bumble-bees. An interesting fact in these cases is that the food given the larvæ by the queen is supplied from her own body, by regurgitation through the mouth, no food whatever being brought into the nest from the time that the queen first begins to lay eggs until this first brood is matured.

Another method of colony founding is by the withdrawal of young fertilized queens each with a group of workers from an old and over-populous community. Still other methods are those, recently carefully worked out by Wheeler and other students, in which queen ants of one species found colonies by the aid of workers of other species. Several phases of this method have been observed. In one phase a queen enters a colony of an alien species and decapitates its queen or is the occasion of her being killed off by her own workers. The intruding queen is then adopted by the workers and proceeds to lay eggs whose hatching larvæ are reared by the alien workers and a compound or mixed colony is thus formed. In another phase of this general method a queen enters a colony of another species, snatches up the worker brood and kills any of the workers or queens that endeavor to dispute her possessions. The ants hatch with a sense of affiliation with their foster mother and proceed to rear her eggs and larvæ as soon as they appear. Here, too, the colony is formed by a mixture of two species, but the workers produced by the intrusive queens inherit her predatory instincts and therefore become slave-makers. They keep on kidnapping worker larvæ and pupæ from the nests of the alien species, carry them home, and eat some of them but permit many to mature, so that the mixed character of the colony is maintained.

The observation and study of ants' ways must be mostly

done in the field, but some species readily live in artificial nests prepared for them indoors. These nests can be so arranged that much of the home life of the ants can be observed.

A simple formicarium, or ant nest, may be made by mounting an inverted bell glass on a wooden block which is set like an island in a shallow pan of water. Enough of the contents (soil and ants) of a nest should be brought in and transferred to the bell glass to fill it about half full. A cover of dark paper or cloth should be placed around the bell glass as high as the soil fills it, in such a manner that it may be readily removed at times of observation. The ants in their nest building will make some of their run ways and chambers next to the darkened glass, and, by removing the cloth, may be seen at work.

Janet, a distinguished French student of ant life, uses a block of porous earthenware in which several little chambers or hollows have been made, connecting with each other by little surface grooves, the whole covered with a glass plate, and over that an opaque cover. Into a cavity at one end of the block he puts water which soaks some distance along the length of the block, thus rendering some chambers humid, while others at the far end are dry. He gives the ants no soil, forcing them to use the already made chambers. This formicarium reveals, therefore, none of the secrets of nest-building, but it does reveal admirably a host of those interesting processes connected particularly with the life history of the individuals of the colony.

Miss Adele Field, an American student of ants, has devised a nest (Fig. 93) in which glass is used for the base, outer wall and partitions. A bit of sponge, kept moist, is placed in one of the rooms. The glass base is double thick and placed on thick white blotting paper for background, and the walls and partitions are narrow strips of glass glued to the base with crockery cement. On walls and partitions are glued strips of Turkish toweling. On this is laid a thin glass roof frame for each room. An outer removable roofing of blotting paper makes all the interior of the nest dark, except the food room which should not be covered as it represents the ants' outer world.

Sponge cake, apple, mashed walnut and the muscular parts

of larvæ of insects are among the ants' most liked edibles, says Miss Field.

The extremely highly developed instincts of the social *Hymenoptera* (social wasps, social bees and ants) have led to their being called the most intelligent of insects. But as far as our present knowledge goes we are not justified in attributing any intelligence, in the strict meaning of the term, to any insects. Their behavior is practically wholly controlled by inherited instincts, which fit them to go through a certain life

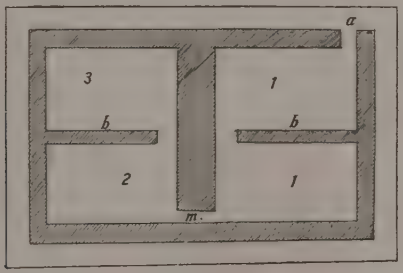


FIG. 93.—Plan of the Fielde ant-nest, ten inches by six inches. *a*, Entrance and exit to food-rooms (1); 2, nursery; 3, sponge-room; *b*, screens; *m*, passage.

routine very effectively, but which leave them helpless if by any chance they are submitted to wholly new conditions. Much experimental work has been done with the wasps, bees and ants, to test their capacities for successful modifications of their behavior, and the weight of authority is against admitting their possession of real reason or intelligence. In this connection the books of Fabre, the French "Homer of insect life," those of the Peckhams, American students of solitary and social wasps, and of Wheeler, the American student of ants, should be read by students. They contain the most fascinating stories of insect life which can be written.

CHAPTER XIX

SCORPIONS, SPIDERS, MITES AND TICKS

The scorpions, spiders, mites and ticks, composing the class *Arachnida* of the branch Arthropoda, are popularly regarded as insects but they differ from the insects in several important respects. They have four pairs of legs instead of three pairs, the body is not divided into three well defined regions, as it is in most insects, but into two, and they have no antennæ. There are also important differences in the respiratory system and other internal structures.

The class is a large one including many diverse forms.

Scorpions.—The scorpions, order *Arthrogastra*, are found chiefly in warm regions. They are usually nocturnal, hiding away under stones or in crevices during the day, and coming forth at night to capture their prey, which consists chiefly of insects and spiders. These they seize and hold with their large pincer-like maxillary palpi and sting with the poison fang at the end of the long narrow part of the abdomen. The first seven segments of the abdomen are broad and flattened, but the last five segments are narrowed, more rounded and whip-like. The last segment bears the poison-fang or sting, the poison from which is quickly fatal to most small animals. Some species are quite poisonous to man, but the kinds found in the United States, while they may inflict a painful sting, are not usually dangerous.

Spiders.—In the spiders, order *Araneina*, the abdomen and the cephalothorax are very distinctly separated but the segments of each region are so closely fused as to be indistinguishable. The four pairs of legs vary in length according to the habits of the different species; some are fitted for running, others for jumping, others for walking over the ground or grass or over delicately spun webs. The pedipalpi, or feet-

like palpi, are sometimes one-fourth to one-half as long as the legs. The mandibles, or *chelæ*, are large and terminate in a slender sharp-pointed fang, through which poison flows when a spider bites its prey. The bite usually quickly kills insects and other small animals but as a rule does not seriously affect man. A few species, however, are very venomous, and a bite from one of them may result in great suffering, rarely in

FIG. 94.—Web of an orb-weaver, *Zilla californica;* the viscid threads are omitted from part of the web; a trap-line runs from the center to a retreat at one side. (Much reduced.)

death. The effect of a spider's bite does not depend altogether upon the kind of spider, the condition of the victim's blood being a considerable factor. Two people may be bitten by the same kind of spider and one suffer little while the effect on the other may be very serious. The most common of the very poisonous spiders, and the only one to be much feared in this country, is the "hour-glass" spider, or "black widow" *Latrodectes mactans*. This is a small-sized sooty black

spider, the female of which has a round abdomen that is marked on the underside by a bright red spot, usually hour-glass shaped. The slender abdomen of the male has three light spots or dashes along the median line and three or four lateral stripes. The very young of both sexes have little black on them and immature females are colored much like the males. This species is cosmopolitan. In the United States it occurs as far north as Massachusetts but is more common in southern regions. These spiders are found in the fields on plants or among loose stones and around houses in dark corners or in boxes or rubbish.

The webs that spiders spin for traps to ensnare their prey or to line their nests or to protect their eggs are made of silken threads of various sizes. Some of these threads are composed of several finer threads united. Spiders produce several kinds of silk, one kind being always viscid and sticky. Most spiders have three pairs of spinnerets, a few having but two pairs, situated at the tip of the abdomen. On the ends of these short finger-like spinnerets are many minute openings through which the fine silken threads are drawn. These openings lie in little papillæ, called spinning spools and spigots. When the tips of the spinnerets are placed close together, the issuing threads all unite into a large strong thread. If the spinnerets are held further apart the broad silken bands are produced.

The great hairy tarantulas of our southern and western states line their burrows with a thin layer of silk. The trap-door spiders usually make a heavier lining sometimes dense and tough, but with a smooth soft silken surface. The door that these spiders make to guard the entrance to their burrow is made of silk and earth, leaves, grass or moss, always resembling closely the ground or ground-covering around it. The common black running spiders that often carry their egg sacs with them and the stout-bodied little jumping spiders which leap on their prey, spin but little web.

The sedentary spiders, or those which spin webs of various sorts to capture their prey, include most of the common kinds. The cob-web weavers, which are one of the trials of the house-

keeper, the funnel-web weavers found in the woods and meadows, and the various orb-weavers are all most interesting and deserve more notice, but as they are of no particular economic importance except as they destroy noxious insects, they will not be discussed further here. The best book about American spiders is "The Spider Book" by Professor J. H. Comstock.

FIG. 95.—Web of a grass spider, *Agalena* sp. (Reduced.)

TICKS AND MITES (ORDER ACARINA)

From an economic standpoint the mites and ticks, constituting the order *Acarina*, are by far the most important members of this class. The body is very compact, the cephalothorax and abdomen being closely fused. This character will serve to separate them from the spiders, the young of which might be mistaken for mites.

Ticks.—The ticks are all comparatively large, that is, they are large enough to be seen with the unaided eye, even in their younger stages, and some grow to be half an inch long. The young when first hatched have only six legs but after the first

moult another pair appears. The sucking beak, which is thrust into the host when the tick is feeding, is furnished with many strong, recurved teeth which hold so firmly that the head is often torn from the body and left in the skin of the host when the tick is forcibly removed.

Ticks are wholly parasitic in their habits. Some of them live on their host practically all their lives, only dropping to the ground when fully mature to deposit their eggs. Others

FIG. 96.—Castor bean tick, *Ixodes ricinus*, not fully gorged. (Magnified about five times.)

leave their host twice to molt in or on the ground. The female lays her eggs, 1000 to 10,000 of them, on or beneath leaves and other litter on the ground. The young "seed-ticks" that hatch from these in a few days, soon crawl up on some nearby blades of grass or on a bush or shrub and wait quietly and patiently until some animal comes along. If the animal comes close enough the ticks leave the grass or other support and cling to their new found host and are soon taking their first meal. Of course thousands of them are disappointed and starve before their

host appears, but as they are able to live for a remarkably long time without taking food their patience is often rewarded and the long fast ended. Those species which drop to the ground to molt must again climb to some favorable point and wait for another host on which they may feed for awhile. Then they drop to the ground for a second molt and if they are successful in gaining a new host for the third time they feed and develop until fully mature and the female is ready to lay her eggs.

FIG. 97.—*Amblyomma variegatum;* several ticks belonging to the genus *Amblyomma* transmit various diseases of domestic animals. (Magnified about six times.)

The presence of even a few ticks on an animal is always a source of annoyance and they often occur in such numbers as to affect seriously some of our domestic animals. Chickens, dogs, horses and cattle, all have their particular kinds of ticks, some of which commonly attack man when the opportunity offers. The bites of ticks often cause great pain. Sickness and death sometimes follow the bite of certain species, but this occurs probably only under exceptional conditions or when the

tick carries the parasite of some disease. The chief importance of ticks, indeed, lies in the fact that they are concerned in the transmission of several diseases that are caused by Protozoan parasites. The Texas fever of cattle and the spotted or Rocky Mountain fever of man are the most important of such diseases in America. These are discussed in Chapter XXVIII.

The chicken-tick, *Argas persicus*, is a very serious pest in the southern states. It has a world-wide distribution, and in Persia, where it has habits similar to the bed-bug, it is one of the most dreaded pests, sometimes becoming so numerous that the inhabitants desert the town rather than try to rid it of the pests.

In Africa the most common tick, *Ornithodorus moubata*, lives in the huts of the natives and has habits similar to the bed-bug. Besides being a source of great annoyance it transmits a disease known as relapsing fever which has at different times been introduced into the United States, but has not become established here.

Mites.—The mites are much smaller than the ticks, so small that they are not ordinarily seen unless one is searching for them. Yet many of them make their presence destructively or painfully evident, for they are not only important pests of cultivated plants, but they attack man and domestic animals.

Perhaps the best known of the mites is the "red spider" of the greenhouses, *Tetranychus bimaculatus*, which is one of the worst pests that occurs in such places. It is found out of doors also and in some regions may totally defoliate almond and prune trees and berry bushes and seriously injure many other plants. These mites do not always have the characteristic red color but during the time that they are feeding they may be light or dark green with dark colored spots. This species passes the winter in the ground. The usual method of control is to dust the trees thoroughly with fine dry sulphur, or the sulphur may be mixed with water, 1 lb. to 5 gallons of water, and applied as a spray. The fumes from the sulphur kill the mites.

Another mite, *Bryobia pratensis*, also commonly called "red

spider," often does much damage to fruit trees, particularly on the Pacific Coast. The eggs are laid on the branches of the tree, where they remain over winter, the young mites issuing about the time the leaf buds open. They may be controlled by spraying the eggs with the lime-sulphur wash (see page 415) just before the eggs hatch in the spring, or by spraying or dusting with sulphur. This same species is often an important pest on clover and grasses and is then known as the clover-mite. In the Mississippi Valley states they sometimes swarm into dwelling houses late in the fall. Dry sulphur dusted around the windows and doors or other places where the mites enter the house, or the free use of pyrethrum after they have gained an entrance, will give relief.

Two other red spiders, *Tetranychus mytilaspidis*, and *T. sexmaculatus*, are serious pests of citrus trees. They are controlled by dusting the trees thoroughly with finely powdered sulphur.

The blister-mites, *Eriophyes*, are minute whitish, grub-like creatures that bore into the tissue of the leaves of many plants. The pear-leaf blister-mite is perhaps the most important of these. They spend the winter in the buds and as the leaves begin to develop they make their way into the tissue, causing green or reddish blisters. They may be controlled by spraying during the late fall or early spring with kerosene emulsion diluted with five parts of water, or with the lime-sulphur wash.

Of the mites that attack man, the young harvest-mites, or "jiggers", are probably the most familiar. Normally these little mites live on plants, but when opportunity offers they will crawl on man or any other animal and burrow into the skin, causing intolerable itching. Where these mites are troublesome, one should avoid sitting or lying on the grass or in other places where they may occur. Harvest men and others whose work exposes them to these pests may get some relief by dusting sulphur in the underclothing and shoes, and by bathing, using a strong carbolic or tar soap, as soon as they return from the fields. Sulphur ointments are also used.

The minute, almost round, whitish mites, *Sarcoptes scabiei*,

that cause the disgusting disease known as itch are seldom found except on unclean people. These mites live normally in the skin, often burrowing deep and causing intense itching. Sulphur ointments and other washes are used as remedies, but on account of their burrowing habits these mites are hard to kill. Cleanliness will prevent infection.

Closely related to the itch-mite of man are several kinds attacking domestic animals, causing mange, scab, etc. The variety infesting horses burrows in the skin and produces sores and scabs, and is a source of very great annoyance. These mites may also migrate to man. Tobacco water and sulphur ointments are used as remedies.

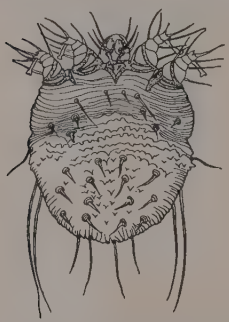


FIG. 98.—Itch-mite, *Sarcoptes scabiei*, female, dorsal aspect. (Greatly magnified; after Fürstenberg.)

Horses and cattle and other domestic animals are also infested by mites of the species *Psoroptes communis*, which cause the common mange. These do not burrow into the skin, but live on its surface in colonies, feeding on the skin and causing crusts or scabs. The inflammation causes the animal to scratch and rub constantly, and often results in the loss of much of the hair. Single animals may be treated with sulphur ointments or with lime-sulphur mixtures; where several are to be treated, dipping vats should be used.

The mites, *Psoroptes communis* var. *ovis*, that cause scab in sheep, are among the worst pests that sheep owners have to contend with. Once introduced into the herd they spread rapidly so that the whole flock may soon become infested. The fleece of scabby sheep becomes rough and felted and is easily rubbed or pulled off, often leaving the sheep very ragged and sore. The most satisfactory treatment for scabby sheep is to hand dip them or drive them through vats containing lime and sulphur or tobacco mixtures.

The common chicken-mites, *Dermanyssus gallinæ*, are about 1 mm. long, light gray or whitish in color, but becoming quite red when full fed. They hide away in any crack or corner where they can find shelter during the day, and come out at night to feed. When numerous they may be serious pests to other animals as well as chickens. Cleanliness will prevent infection. A thorough spraying with kerosene or strong kerosene emulsion will kill all that are reached by the oil. Whitewash helps some. A poorly constructed, badly infected house should be burned. Smooth roosts supended on wires or small iron rods afford few hiding places for the mites.

CHAPTER XX

OYSTERS, CLAMS, MUSSELS, OTHER MOLLUSCS, AND THE SHELL-FISH INDUSTRIES

The oysters, clams, mussels and snails, the molluscs (branch Mollusca) with which we are most familiar, have their soft bodies protected by a firm outer shell which is formed of carbonate of lime. But the slugs, which are common in the garden and in moist places, the beautiful sea-slugs or nudibranchs, which are found in salt water, and the cuttlefish and octopi, which are also marine, all of which also belong to this branch, are not protected by such a shell. In habits and distribution the members of this branch vary as much as they do in structure and general appearance. Many of the snails and slugs live on land, feeding on live or dead and decaying vegetable tissue. Most of the mussels live in fresh water, but all the other members of the branch live in the sea, some at the surface, others at moderate or great depths, many in the sand or mud of shores and shallow bottoms.

The Fresh-water Mussel.—A study of the fresh-water mussel will give one a general idea of the structure of the typical members of this branch. The two *valves* of the shell are held together along the dorsal edge by the horny *hinge-ligaments*. Toward the rounded anterior end there is, on each valve, a prominent elevation, the *umbo*, which marks the oldest part of the shell, and from which extends a series of concentric *lines of growth*. When the mussel is feeding in the bed of the stream the anterior end is buried deep in the mud and only a little of the posterior end is exposed. The valves are opened slightly at the posterior end, and between them may be seen the edges of the mantle that covers the soft body and lines the inside of the shell. When one of the valves is removed it will be seen that the mantle is attached to the inner surface of the shell a

short distance from the edge. The crease on the shell indicating this line of attachment is called the *pallial line*. Near the anterior end of the inner surface of the valve is a rather large distinct impression. This is the point of attachment of the *anterior adductor muscle*. Just behind and above this is the smaller impression of the *anterior retractor muscle*, and behind and below it is the impression of the *protractor muscle*. At the other end of the valve is the large impression of the *posterior adductor muscle* and the small impression of the *posterior retractor muscle*. The anterior and posterior adductor muscles extend from one valve to the other and when they contract the edges of the two sides of the shell are held close together. When these muscles are relaxed the valves are opened slightly by the strong hinge ligament which is stretched tightly when the valves are closed. The retractor and protractor muscles govern the movement of the foot.

Where the mantle covers the body it is a thin delicate membrane, but the free part, below the pallial line, is somewhat heavier, and the edges are thicker. At the posterior end the thickened fringed portions of the two mantle lobes form two short tubes, the *inhalant* and *exhalant siphons*. The cilia on the fringes of the mantle cause a current of water to flow in through the lower or inhalant siphon into the *mantle cavity*, the space inclosed by the mantle lobes. Here the water bathes the inner surface of the mantle and the gills, and passes through the gills to a space just above them known as the *supra-branchial* cavity. In this space it passes backward again and out through the upper or exhalant siphon. The mantle is an important organ of respiration, for as in the gills of fishes, oxygen is taken from the water and carbon dioxide passed out through its thin delicate walls. The shell is the product of the secretions of the mantle. Over its whole surface the mantle is constantly secreting a thin layer of carbonate of lime which serves to thicken the older parts of the shell and to extend and harden the thin soft margins.

When the mantle is removed from one side of the body the large muscular *foot*, the thin delicate leaf-like *gills* and the soft *visceral mass* of the body are exposed. The foot is large and

quite firm, somewhat triangular in shape, and is capable of being extended beyond the edges of the shell for a considerable distance. It is by means of this organ that the animal plows its way through the mud or sand in which it lives. The gills are two pairs of flattened, ribbed, membranous folds which hang down into the mantle cavity from each side of the body. The water bathing these gills and passing up between them comes in very close contact with the minute blood-vessels with which the gills are abundantly supplied so that the transfer of gases from the water to the blood and from the blood to the water can readily take place. The body is not divided into well-defined regions. Just below and back of the anterior adductor muscle is the *mouth opening*. On each side of it, looking somewhat like little gills, are two pairs of *labial palpi* whose function it is to convey to the mouth the minute plant or animal organisms that are carried in by the water. Through a short *esophagus* these particles, which are the food of the mussel, pass into a rather large *stomach* and from that into a long narrow *intestine* which is coiled in the base of the foot and the visceral mass. The posterior part of the alimentary canal, the *rectum*, is a long straight tube extending through the *pericardium* and opening into the supra-branchial cavity close to the exhalant siphon.

The pericardium is the space in the upper portion of the visceral mass just below the hinge-ligament. It is covered by a delicate membrane, and contains the *heart* and some of the blood-vessels. The heart consists of a single *ventricle*, which surrounds part of the rectum, and a right and left *auricle*. When the ventricle contracts it sends the blood forward and backward through large blood-vessels, the *anterior aorta* and the *posterior aorta*. Part of the blood is carried directly to the mantle where it is aerated and then returned to the heart. The rest of the blood is carried to various parts of the body and finally collects in a space, the *vena cava*, just beneath the pericardium. From the vena cava the blood passes into the excretory organs, the *kidneys*, which lie just beside it, and on down into the gills and finally back to the heart where it enters the auricles.

Instead of a series of ventral ganglia and a more or less specialized brain as is found in the insects, worms and some other invertebrates, the nervous system of the mussel consists of three scattered principal groups of ganglia connected by nerve cords. Lying one on each side of the esophagus are the *cerebro-pleural ganglia.* They are connected with each other by a nerve which passes over the esophagus, and by larger nerves with the *pedal ganglion* in the foot and the *visceral ganglion* which lies near the posterior adductor muscle.

The sexes of the mussels are separate, that is the ova and spermatozoa are produced in different individuals, but the reproductive glands, or gonads, of the two sexes are very similar. They form a glandular mass of tissue filling the base of the foot. The ducts from the ovaries and testes open near the base of the gills. The spermatozoa are carried from the body with the water that passes out through the exhalant siphon, and find their way to another mussel with the incoming water currents. The eggs pass into the supra-branchial chamber, but instead of passing on out of the body remain there until they are fertilized by the spermatozoa from another individual. They then drop down into the outer gills, which serve as brood chambers. Here the young are held for some time, and develop bivalve shells which enclose them. In some species the margin of the shell is provided with stout hooks, but in others it is without them. Thus armed, the young, or *glochidia*, as they are called, pass into the water. When touched the shell closes quickly and firmly. If the young come in contact with the fins or gills of a fish the snapping shut of the shell may serve to attach them to it. The forms with hooks on their shells are more often found on the fins of the fish, the hookless kind on the gills. Once attached, their presence causes an irritation of the tissues of their host which results in a growth or cyst that soon covers them over. In this condition they remain for some time, drawing their nourishment from the host and undergoing the transformations that change them to small mussels which finally drop to the mud where they continue their growth, feeding on small organisms, both plant and animal, which are taken from the water entering the mouth cavity. The

knowledge of this relation of the fish to the mussel is of prime importance in the attempts that are being made to restock some of the mussel beds that have been depleted on account of the increased demand for the shells for the making of pearl buttons.

Mussels and Buttons.—Until about 1891 no use was made of the shells of fresh-water mussels. But at this time it was found that excellent pearl buttons could be made from these shells, and so there has sprung up an industry spread throughout the central part of the United States that has a value of more than $6,000,000 annually and gives employment to hundreds of people. The Government has established a station for the propagation of mussels in order that depleted streams may be restocked and new areas made productive. Mussels containing the developing glochidia are teased up in water and this water is poured into tanks containing fish. When their fins and gills are well covered with the glochidia the fish are liberated in the streams that are to be stocked with the mussels.

Mussels and Pearls.—In an earlier chapter reference has been made to the fact that pearls are produced in many molluscs by the pearly nacreous substance, of which the shell is formed, being deposited around certain parasitic worms that are found in the body of the animal. When such secretions are irregular in shape they are usually called baroques, or slugs. When round or pear-shaped, or of some other regular shape, they are called pearls.

It is not an uncommon thing to find baroques or slugs in the fresh-water mussels, some of them very beautiful. These are usually formed around certain parasitic flat worms, a Distomid having the muskrat or otter as one of its hosts, being a common form.

Perfect round pearls of delicate luster and great value are also often found. Recent investigations have shown that the egg or the dead body of a small water-mite may form the nucleus around which the pearl is formed, the most perfect pearls probably being formed around the eggs. These mites, *Unionicola* (*Atax*), live parasitically in the gills or mouth cavity of the mussel, and when they lodge in the tissues in such a way

as to cause irritation, the mussels, as a means of protection, cover them over with the pearly layer. These pearls vary in value from a few cents or dollars up to hundreds of dollars. Perhaps the most famous of all the fresh-water pearls is the "Queen Pearl," which was found in a New Jersey stream in 1857. It was sold by the finder for $1500, but is now valued at about $10,000. Occasionally some particularly valuable pearls will be found in a new region, and during the "pearl fever" that follows, thousands of dollars worth of pearls may be found, but the mussel beds of the streams are usually almost or quite depleted. Formerly the shells thus gathered were left on the bank to disintegrate, but they are now used in the important button industry.

Fresh-water mussels are sometimes used for food. The great shell heaps, or "kitchen middens," found in many places show that they must have formed an important part of the food of the early inhabitants of this and other countries

FIG. 100.—A chiton, *Ischnochiton magdalenensis*. (Reduced.)

Classes of Mollusca.—The branch Mollusca (L. *mollis*, soft) is divided into five classes. The class *Pelecypoda* (Gr. *pelekys*, axe, *pous*, foot) is the largest and most important group, including the mussels, clams and oysters and others that furnish an abundance of cheap, palatable and nutritious food. The name *Pelecypoda* means "hatchet-foot," and refers to the fleshy foot or organ that enables the clams and mussels to dig or plow their way through the mud. The name *Lamellibranchia*, referring to the lamella-like gills on each side of the body, was formerly used for this class. As all the members of the class

are inclosed in a shell composed of two parts or valves they are commonly referred to as bivalves.

The class *Gastropoda* (Gr. *gaster*, stomach; *pous*, foot) includes the snail, slugs, periwinkles and many other molluscs that are either naked or furnished with a shell composed of a single piece.

The *Cephalopoda* (Gr. *kephalē*, head; *pous*, foot) include squids, octopi, cuttlefish and the nautilus.

The members of the classes *Amphineura* (Gr. *amphi*, around; *neuron*, nerve) and *Scaphopoda* (Gr. *skaphe*, hollow; *pous*, foot) are much less common and are of little or no economic importance. The first includes the chitons, which have segmented shells and are fairly common on rocks on the California coast. The tooth-shells sometimes found along the northern sea beaches belong with the peculiar somewhat worm-like members of the class *Scaphopoda*.

Class Pelecypoda

The Mussels.—They are many genera and species of fresh-water mussels, and they are to be found in suitable streams and lakes in almost all parts of the United States. Their life history and importance have just been discussed. The salt-water mussels differ from those in fresh water in several respects, the most noticeable of which is in shape and in the presence of a number of fine tough threads, the *byssus*, which serve to attach the mussels to rocks or other substances on which they are growing. These mussels often occur in great masses over the rocks and piles or on tide flats wherever they can find a place to attach themselves. They are often serious pests on oyster beds, occurring in such numbers as to smother the oysters or starve them by taking a large part of the food that would otherwise go to the oysters. The salt-water mussels are often used for food, and can advisably be thus used more than they are at present. They occur in abundance on both Atlantic and Pacific coasts of our country, and are easily gathered at low tide.

Clams.—In most of the clams the portion of the mantle that forms the siphons in the mussels is especially developed and

produced into a long neck-like process. This enables the clam to bore into the mud or sand for some distance and still keep the end of the siphon in the water. Those who have never been near the sea-shore where they could take part in a clam-bake have at least enjoyed their clam chowder in their inland homes even if it were made from the canned article. Hardly a beach along any of our coast lines but furnishes an abundance of one or more species of clams. Along the North Atlantic coast the soft clam, *Mya arenaria*, is one of the most

FIG. 101.—The common sea-mussel, *Mytilus edulis* L. (Reduced.)

important of the clams. At one time it occurred in seemingly unlimited numbers, but on account of wasteful and destructive methods of gathering them many of the best beds are now nearly depleted. Most of these tide flats may be made to yield abundant supplies again under the methods of cultivation and protection that are now being adopted in some places.

The hard clam, or quohog, or little-neck clam, *Venus mercenaria*, is the most important clam from New York southward. Unlike the soft clam, whose shell is comparatively light and often does not close tightly along the edge, the hard clam has a heavy shell that closes very firmly.

Other species of clams and two or more kinds of scallops, *Pecten*, occurring along the Atlantic coast, are used for food. The scallops differ from the clams in having deep grooves radiating from the hinge to the edge of the shell. Some are beautifully colored. The meat of many of them is very dainty.

The soft clam has been introduced into the waters of the Pacific Coast States, doubtless with the shipments of eastern oysters. There it is

FIG. 102.—Soft-shell clam, *Mya arenaria* L. (Reduced.)

FIG. 103.—A geoduck or giant clam, *Glycimeris generosa*, which attains a weight of five or six pounds. (Much reduced.)

known as the "eastern" clam, but has not yet found much favor in the markets because there are several native species that are more in demand. One of the most common of these is the hard shell or little-neck, *Tapes staminea*, which seems to take the place of the hard clam of the east coast. The great Washington clam, *Schizothærus nuttalli*, and the butter-clam, *Saxidomus nuttalli*, are common in many places on the northwest coast. One of the most remarkable clams in the United States is the giant "geoduck" (earth duck), *Glycimeris generosa*, which sometimes weighs as much as

six pounds and has a siphon that may be extended eighteen to twenty-four inches. The body is very large, but the shells are so small that they only cover the sides of the clam and the great white mass that extends beyond the shells and the long siphon looks not unlike the breast and neck of a duck, the shells representing the folded wings.

In the hard, smooth, wave-beaten, sandy beaches of the North Pacific are to be found the "razor-clams," *Machera patula*, which are undoubtedly the finest of all the clams. The meat is white and tender and most delicately flavored. The canneries that have been established along the coast are fast depleting the supply of these choice clams.

Oysters.—Much more important than the clams, though less numerous, are the oysters, two species of which occur along our coasts and are used for food. Some of the most extensive natural beds occur in Chesapeake Bay, but other beds are found as far north as Prince Edwards Island and as far south as the Gulf States. Many excellent beds are found in Long Island Sound. The eastern oyster, *Ostrea virginiana*, is unisexual, that is, the ova and spermatozoa are produced in different individuals. During spawning season the female produces sixteen to sixty millions of ova which are set free in the water to meet by chance the spermatozoa from the male. If this union takes place, the ova are fertilized and soon lose their original pear shape and become quite round. If they are not fertilized they soon perish. Within two or three hours after fertilization these ova, which are single cells too small to be detected with the unaided eye, begin to divide, and in two hours more have changed from single round cells into masses of cells, the masses themselves being rounded and about the size of the original egg cell. A little later, small thread-like projections, or cilia, begin to appear on one side. The embryos have now reached the swimming stage, for by means of these cilia they are able to move about through the water at will. They remain in this stage from three to six days, or until the shells have begun to form, when they sink to the bottom, and, if they are fortunate enough to strike some suitable hard object, they become attached and begin to take on the character of an

adult oyster. From this time on the young oysters are less exposed to danger, but the number of them that reach maturity is very small when compared with the number that perish or are destroyed in one way or another.

The young oysters when first attached are called "spat"; when a little older this spat, now called "seed," may be transplanted to new beds, which are stocked in this way.

FIG. 104.—Young (spat) of the west-coast oyster, *Ostrea lurida*, attached to rock. (Reduced.)

In some regions clean shells or other "cultch" are distributed over the beds just before the spawning season in order that there may be plenty of clean hard surfaces for the young embryos. The oysters are ready for market in from three to five years, and are gathered from their beds by means of long-handled tongs or dredged up by means of dredges and power

boats. It has been estimated that more than twenty-five million bushels of oysters are gathered from the beds in the United States each year.

The west-coast oyster, *Ostrea lurida*, is much smaller than the eastern oyster and has a much thinner shell. It differs also in being hermaphroditic and viviparous; that is, both ova and spermatozoa are produced in the same individual and the eggs are fertilized in the gill and mantle cavities and here also they pass through the early stages of development. At spawning season, when these young embryos are set free, they have already reached the swimming stage and are soon ready to attach themselves to some convenient shell or other collector, where they remain fixed through life.

The area available for oyster cultivation is much less on the Pacific coast than on the Atlantic, but the total output of oysters from the state of Washington amounts to about $300,000 annually. Many years ago shipments of eastern oyster spat or seed were made to the Pacific coast and planted in San Francisco Bay where they were allowed to remain until they reached a marketable size. Now many carloads are shipped from the east each season and planted on the tide flats in California and Washington, the introduced oysters attaining a good size and a flavor hardly excelled in their native waters. On account of the low temperature of the water during the spawning season most of the young of the eastern oyster are killed while they are swimming at the surface, and so the beds of eastern oysters have to be replanted when the marketable oysters are removed.

There are two common species of oysters native to Europe. The smaller flat oyster, *Ostrea edulis*, occurs along the northern shores, and in many respects resembles our Pacific coast oyster. Like the latter it is hermaphroditic. The Portuguese oyster, *O. angulata*, is found on the southern shores and resembles more our east-coast oyster in size and methods of breeding, but is not so highly esteemed for food as the smaller northern oyster.

The European oysters have been cultivated since the earliest times, and in many places the collecting of the spat on especi-

ally prepared collectors, the transplanting and caring for the seed and the final marketing of the oyster after it has been fattened and often flavored to suit the taste of a fastidious public, furnishes employment to many people along the sea coasts.

Many other species occur in other parts of the world, where they are usually important articles of food.

Shell-fish and Disease.—In feeding, the oysters, clams and mussels may take into their body any minute particles that are to be found in the water where they are lying. Thus it will be seen that any impurities that are in the water may readily affect the bivalves living in it. It sometimes happens that oyster or clam beds are situated so near the outfalls of sewers from some city that the water is always polluted. Shell-fish coming from such places are usually plump and look most inviting, but as they may contain typhoid germs and other dangerous organisms they are to be avoided. The interest that has been aroused in this subject during the last few years has been the cause of much careful study, and, while the danger is a very real one, the rigid supervision that is now kept over many of the sources from which this important food supply comes, makes most shell-fish safe. If they are thoroughly cooked before being eaten the harmful organisms are destroyed. Oysters that have been "freshened" or bloated by being transferred to fresher water for a few days or hours should never be eaten raw, as the places where this process is carried on are too often in dangerous proximity to sewer outfalls. A strong public sentiment against such practice will insure its discontinuance.

Pearl-oysters.—The "pearl-oyster" of the South Seas is really not very closely related to our oysters. It is more of the shape of our common pectens, and has a strong byssus by which it attaches itself, at least during its earlier stages, to rocks or corals. The shell of some species is quite heavy, and the wonderfully iridescent inner layer is known as "mother-of-pearl." The pearl-shells form an important article of commerce, as the mother-of-pearl is used in the manufacture of many articles. The pearls themselves, which are formed in

the same way as that already described for the fresh-water pearls, may have, when large and of perfect shape and luster, a very great value. The recently attained perfection in the making of imitation pearls may somewhat lessen the market value of true pearls, but the pearl-fisheries are still of great importance.

For more than two thousand years Ceylon has been the center of the pearl-fisheries industry, but many valuable pearls and much better mother-of-pearl shells are found in the waters of other tropical islands.

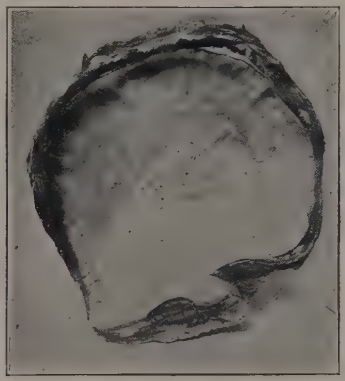


FIG. 105.—Inner side of a pearl shell. (Reduced).

Teredos.—Very unlike any other members of this class in general appearance and habits are the teredos or ship-worms that so often do great damage to any timber that is in salt water. The young teredo is a free-swimming embryo like the young of other molluscs, but it soon settles on some piece of submerged wood and begins to burrow into it. As it grows and develops its small bivalve shell, it bores deeper into the wood, lining its burrow with a shell-like calcareous deposit. As the ends of the siphons are kept close to the entrance of the burrow, the animals soon become very much elongated and

worm-like, and indeed are more commonly thought to be worms than bivalve molluscs. They bore into the wood only for protection, and do not feed upon it. Their food consists of minute organisms that are taken into the body through the siphons.

Teredos are very serious pests on the piles of wharves, and on dykes, ships' bottoms and any other wood that comes in contact with salt water. In some places they are so abundant that a two-inch plank may be completely honey-combed and destroyed in less than a year. The only protection is to cover the wood with some substance which the teredo cannot or will not penetrate. Heavy coatings of copper or verdigris paint are often used, but they must be reapplied frequently. Certain other Pelecypod molluscs have the remarkable habit of boring into solid rocks far enough to protect them.

Class Gastropoda

Snails.—Snails are very common objects in water and on land. They all have shells, which may be conical or spire-shaped or flattened. The most common snails have spiral, more or less cone-shaped shells. One group, the pulmonate snails, including many common aquatic and terrestrial forms, do not breathe by means of gills as do most other molluscs. On the right side of the body near the anterior end is an external opening that leads into a sac, the so-called "lung." The inner surface of this sac is abundantly supplied with fine blood-vessels through the walls of which oxygen is taken from the air and carbon dioxide thrown off. These snails are vegetable feeders and are sometimes serious pests among flowers and in the garden.

The members of another group of common pond snails have gills and no lung-sac. These live on the bottom of the ponds and feed on animal rather than vegetable food.

Most of the snails and the slugs have two pairs of "horns" with the eyes on the tips of the second pair. Some snails have only one pair, which are used as feelers, the eyes being situated at the base of these feelers.

Slugs.—The small slimy slugs that are often so common in moist places are very serious pests in vegetable and flower gardens. They hide away in some cool, dark place during the day, and at night come out and feed upon any succulent plants that they can find. They do particular damage to early young plants, often destroying them as fast as they come up. No very efficient remedy has been suggested, but their numbers may be somewhat reduced by one or more of the following methods. The ground around the plants should be examined for the slugs, which may easily be destroyed. If ashes or air-slaked lime is then spread about the plants the slugs will not bother them as long as the ashes or lime remains perfectly dry

FIG. 106.—The giant yellow slug of California, *Ariolimax californica*. (This slug reaches a length when outstretched of twelve inches.)

and does not form a crust over which the slugs can crawl. Boards or stones afford good hiding places and may be placed in the garden as traps to be examined each day. Lettuce or cabbage leaves thrown on the ground are attractive baits and are also good hiding places which can be easily examined every morning. If the plants are examined at night with the aid of a lantern many of the slugs may be found and destroyed. Spraying with arsenate of lead or kerosene emulsion does some good, the first poisoning the slugs, the latter killing those that it touches and being more or less effective as a repellent.

Marine Gastropods.—Hundreds of shell-forming Gastropods are found along every sea-shore. These present a wonderful variety of shape and size and color. Some of them are most beautifully colored and fantastically shaped. The great cowries with their delicately colored porcelain-like shells, the lim-

pets so common on the rocks everywhere, the helmet-shells from which cameos are cut, and hosts of others all belong to this group. The large sea-snails and the much smaller but more numerous drills (family *Muricidæ*) are often of serious economic importance. The sea-snails bore holes by means of their roughened tongue-like organ, the *radula*, and an acid salivary secretion through even the thickest-shelled clams, and suck out the soft body of the victim. The oyster-drills, of the genus *Urosalpinx* and of other genera, drill holes through the oyster shells in the same manner, and as they often occur in great numbers on the oyster beds they may destroy many oysters. Some of them have a habit of collecting in great masses at their breeding season, and are sometimes gathered

FIG. 107.—Two kinds of oyster-drills; large one, *Polynices lewisi*, Gould; small one, *Thais lamellosa*. (Reduced.)

and used for food. Many *Muricidæ* when crushed exude a reddish-purple fluid which in olden times was used as a dye famous under the name of Tyrian purple.

Abalones, or ear-shells, which are particularly abundant along certain parts of the California sea-coast, are of interest because of their economic importance. The animal lives attached to a rock by a great muscle which fills most of the firm ear-shaped shell that covers it. The outer side of the shell is rough and dull-colored but the inner surface is smooth

and wonderfully irridescent. It is much prized for making buttons and for other purposes for which mother-of-pearl is used. Very beautiful and valuable baroque pearls are sometimes found in the abalones. The meat is dried or canned and used for stews or chowder. Large quantities of dried or canned abalone meat are shipped each year to China.

The nudibranchs or sea-slugs are doubtless the most beautiful of all the molluscs. They are without a shell, and the gills are usually in the shape of delicate, freely projecting tufts often arranged in rows along the back. The gills, and indeed the whole animal, are often most strikingly and beautifully colored.

FIG. 108.—Three Pacific coast nudibranchs; *Doris tuberculata* (in lower left-hand corner), *Echinodoris* sp. (upper one), and *Triopha modesta* (at right).

CLASS CEPHALOPODA

Squids, Cuttlefishes and Octopi.—Both in habits and structure the squids, cuttlefishes and octopi, or "devil-fishes," differ greatly from the other members of this branch. Most molluscs move but little or not at all except as larvæ, but the *Cephalopoda* are very active all their life, swimming swiftly through the water. The name *Cephalopoda* refers to the fact that the foot assumes the appearance of a number of arms or

appendages of the head. The head is more or less definitely set off from the rest of the body. The eyes are large and highly developed. The main part of the foot is composed of a series of eight or ten freely movable tentacles or "arms" surrounding the mouth. These arms are provided with numerous sucker-

FIG. 109.—A devil-fish, *Polypus apollyon*. (Much reduced.)

like discs which enable the animals to hold fast to the rocks or to catch and hold their prey, for they are all carnivorous.

The devil-fishes, genus *Octopus* (*Polypus*), have only eight arms and so are known as Octopods. These arms or tentacles may attain a length of fifteen feet or more, and with their great sucker-like discs form very effective means of offense or defense. The body is sub-spherical and without a shell. Their

terrifying appearance has been the basis for many weird sea tales. The argonaut, or paper-nautilus, *Argonauta argo*, secretes a beautiful thin shell for the protection of the eggs.

The cuttlefish, or sepias, and the squids, have in addition to the eight arms of the Octopods, two other long slender

FIG. 110.—A squid, *Loligo opalescens* juv. (Reduced.)

arms, with suckers near the ends only, and so are known as Decapods. The body is longer and better fitted for swimming. Some of the squids attain enormous size, having a body-length of twenty feet and arms thirty to thirty-five feet long. The smaller squids are often very numerous and are commonly used for bait by the fishermen of many regions. The cuttlefish

have in their body a horny calcareous substance known as the "bone" or "pen." This is the cuttlefish bone that is used to feed canary birds. True sepia ink is also a product of these creatures. The ink is a dark secretion which the cuttlefish discharges when it is irritated or frightened. This clouds the water and allows the animal to escape from its enemies.

The chambered pearly nautilus, genus *Nautilus*, belongs to the only living genus of a group which was much better represented in former geologic times.

CHAPTER XXI

FISHES AND FISHERIES

With this chapter we begin the discussion of the last and highest branch of the animals. The branch is more commonly known as the *vertebrates*, because all except a few of the lower forms in it possess a backbone made up of a number of separate vertebræ. This character separates them from all the other animals that we have studied. Those forms that do not have a vertebral column have, in common with the vertebrate forms, in some stage of their development, a peculiar structure called the *notochord*, which consists of a series or cord of cells extending longitudinally through the body just below the spinal nerve-cord. The presence of this notochord and of gills in the neck region are about the only claims some of the members of the branch have to be classed with the vertebrates, and it is on account of the notochord that the name *Chordata* has been given to the branch.

The branch is divided into nine classes of which the members of five are familiar while those of the other four are strange small marine animals not at all popularly known. In the class *Adelochorda* (Gr. *adēlos*, concealed; *chordē*, cord) which includes the worm-like *Balanoglossus*, the notochord is imperfectly developed and for this reason some zoologists do not consider it as belonging to the Chordata. These animals occur only in certain places in the sea and are of particular interest only to special students or investigators. In the class *Urochorda* (Gr. *oura*, tail; *chordē*, cord), of which the ascidians, or sea-squirts, are common examples, the notochord is present only in the larval stage. The ascidians when born are free-swimming tadpole-like creatures with a short notochord and a fairly well-developed nervous and digestive system, eyes and auditory organs. These larvæ soon attach

themselves to a rock or some other firm substance, and all of their organs become very much reduced and simplified. The adult ascidian is a degenerate, sac-like organism looking as much like a plant as an animal, and showing in no way the relation to the vertebrates that is suggested by the larva.

As these two classes are so unlike each other and so different from the vertebrates they are often considered as two distinct subbranches of the Chordata and all the other classes are included in a third subbranch, the *Vertebrata*. In almost all

FIG. 111.—An ascidian, or sea-squirt, from the coast of California. (After Jordan and Kellogg.)

of the *Vertebrata*, the notochord, which is present in the early stages of development, is replaced, in the later stages, by a cartilaginous or bony backbone or spinal column.

The class *Leptocardii* (Gr. *leptos*, small; *kardia*, heart) includes the primitive lancelet, in which the notochord is persistent and unsegmented. Lancelets occur in the sand in shallow water

along the Atlantic seacoast. They are slender, translucent little creatures of very lowly organization.

The class *Cyclostomata* (Gr. *kyklos*, circle; *stoma*, mouth) includes the lampreys and hag-fish, slender, eel-like forms having a sucker-like mouth but no jaws. The lampreys, genus *Petromyzon*, occur in both fresh and salt water, those living in the sea ascending rivers to spawn. They sometimes attach themselves to fishes by their sucker-like mouth and rasp the skin and suck the blood. In this way they are of economic importance as they may thus destroy some of the food fishes. The hag-fish may burrow into the abdominal cavity of other fish and devour the entire flesh and viscera in a short time.

The other five classes are the familiar ones of the *Pisces* (L. *piscis*, fish), or fishes, *Amphibia* (Gr. *amphi*, on both sides; *bios*, life), or frogs, toads and salamanders, *Reptilia* (L. *repo*,

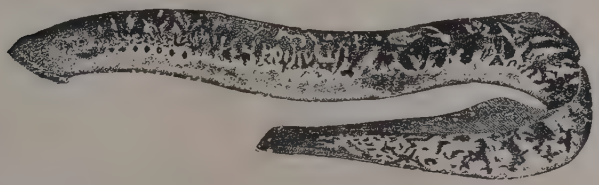


FIG. 112.—A lamprey, *Petromyzon marinus*. (After Goode.)

to creep), or turtles, snakes and crocodiles, *Aves* (L. *avis*, bird), or birds, and *Mammalia* (L. *mamma*, breast), or mammals.

The fishes constitute the largest class of vertebrate animals, about 13,000 species being known, 3000 of which live in North America. They occur in almost all ponds, lakes and streams and in the ocean, and vary in size from the great basking shark, *Cetorhinus*, which reaches a length of thirty-six feet, to the dwarf goby, *Mistichthys*, which is less than half an inch long. Between these extremes is found every variety in size, form and relative proportions. The body may be greatly elongated and almost cylindrical as in the eels, or long and flattened from side to side as in the ribbon-fishes, or globe-shaped as in the globe-fish.

In habits too they differ as much as in size and shape. Some live only in quiet ponds or lakes, others occur in the swiftest mountain streams; some live only in fresh water, others in the brackish waters of the bays or the salt water of the sea. Certain kinds live close to the surface of the water, others at moderate depths and still others in the deepest parts of the ocean.

General Form and Structure.—A typical fish, such as a sunfish or perch, has the body more or less pointed, the sides somewhat flattened, the head wedge-shaped, and in many other ways shows a body formed for moving rapidly through the water. Most fish have the body covered with scales, although many have the skin naked or covered with small scales so hidden in the skin as to be hardly visible. The scales are small horny or bony plates, outgrowths of the skin, which usually overlap each other like shingles. The number, shape and size of these scales are characters that are much used by ichthyologists in classifying fishes. Three regions of the body may be recognized, the head, the trunk and the tail, the latter comprising that part of the body beyond the anal opening. On the head are two usually conspicuous eyes set in protective sockets. There are usually no eyelids, the skin of the body being continuous, but transparent, over the eyes. Fishes are near-sighted and vision is probably not very precise, although the trout and some others seem to possess a very keen eyesight. In some of the deep sea fishes and in some cave-dwelling species the eyes are rudimentary or wanting.

The mouth in most fishes is comparatively large and transverse, and the jaws usually bear numerous teeth that enable the fish to bite or hold their prey. Some fishes, however, have the mouth small and round and fitted for sucking rather than biting, and many have few or no teeth.

The nostrils are paired openings usually situated in front of the eyes. They end in a pair of *nasal sacs* and do not open into the roof of the mouth as they do in mammals, and so have no relation to breathing. The sense of smell is relatively acute in most fishes. On each side of the head is a flap-like *gill-cover*, or *operculum*, the posterior margin of which

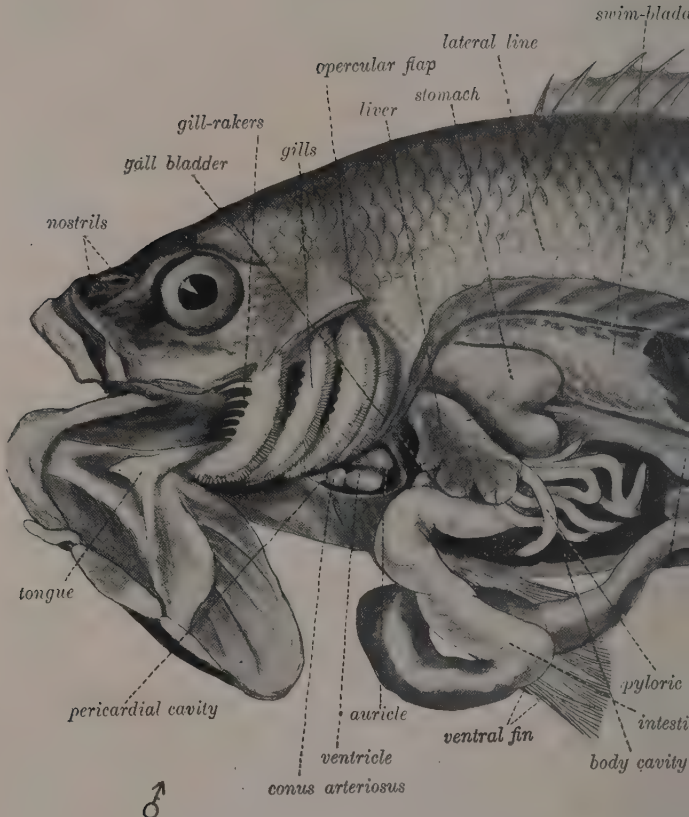
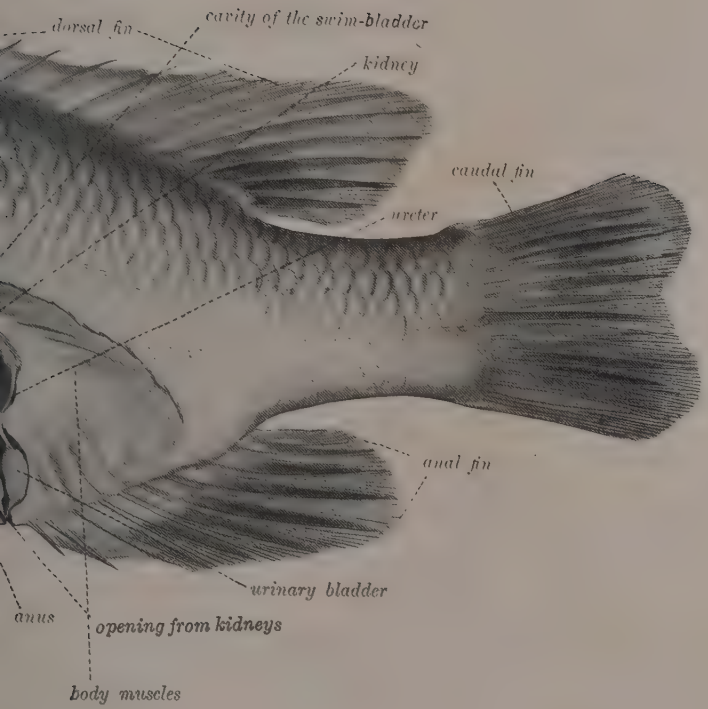

swim-bladd
lateral line
opercular flap
stomach
liver
gill-rakers
gills
gall bladder
nostrils
tongue
pericardial cavity
auricle
ventricle
conus arteriosus
ventral fin
pyloric
intesti
body cavity
♂

FIG. 113.—Dis



the golden sunfish.

is free so that water may be taken in at the mouth and pass out through the gill-openings. The *gills* consist of a series of slender filaments attached to bony arches. In these filaments a supply of blood is constantly circulating in fine capillaries through the walls of which carbon dioxide is given off and a fresh supply of oxygen taken from the water that is flowing over the gills. In some of the sharks and in some of the flat rays that lie on the sea-bottom a pair of *spiracles* or small openings occur behind the eyes. These open into the mouth and the water can pass in through them instead of through the mouth-opening. On the head of some fishes are to be found soft pendulous filaments, sharp spines, or other appendages. On the trunk usually occur two pairs of paired fins and two or more unpaired fins.

Just back of the gill-openings are the *pectoral* fins, which are homologous with the fore limbs of the other vertebrates. On the ventral side of the body is another pair of fins, the *pelvic* fins, which correspond to the hind limbs. The pelvic fins may be placed well forward, almost under the head, or well back on the body. The unpaired or *median* fins consist of the *dorsal* fin above, the *anal* fin below, and at the posterior end of the body, the *caudal* fin, or tail. Salmon and trout, and a few other fishes, have in addition to these a small, soft *adipose* fin between the dorsal and caudal fins. The median fins are folds of the skin of the body supported by more or less firm rays. The stiff, unjointed rays are known as *spines* and the others, which are softer and made up of little joints, are called *soft rays*.

The stiff sharp spines in the paired median fins are often very effective weapons of defense as a wound made by them may be very severe, particularly when made by the spines with serrated or ragged edges. Some of the scorpion-fishes and others secrete a poison which is introduced into the wound made by the spine.

Along the side of most fishes, extending from the head to the caudal fin, is a series of modified scales which mark the *lateral line*. This lateral line is subject to considerable variation in regard to its position and structure. In connection

with it are mucous tubes and other pores. It is well supplied with nerves and it has been thought by some to be an organ of sense, perhaps some sense that man does not possess and therefore does not understand. It is closely associated with the ear-sac, and possibly has some similar function, that is, of determining vibration waves.

Most fishes are colored in such a way that they are hard to detect in their natural environment, and are thus protected, in a measure, from their natural enemies. Some show bright colors only at breeding time while still others are beautifully and brilliantly colored at all times.

The skeleton consists of the many bones composing the skull and jaws, the shoulder girdle, the backbone with a varying number of ribs and intermuscular bones, and the bones supporting the fins. Most of these bones are comparatively soft having little lime in them. Indeed, in many cases they are mere cartilage. The small free intermuscular bones lie imbedded in the flesh, and when abundant materially lessen the value of the fish for food.

The *air-bladder* or *swim-bladder* is a characteristic structure that is found in many fishes. In the garpike, bowfin and the lung-fishes it is connected with the esophagus and is used as a lung for breathing. In others it is joined through the modified bones of the neck to the organ of hearing. Its normal function seems to be hydrostatic, that is, it helps to keep the fish of the same specific gravity as the water by the absorption or secretion of gas.

Most fishes lay eggs which are fertilized outside of the body by the male pouring the milt, or spermatozoa, over them as they settle into the gravel or other places where they are to develop. A few make more or less elaborate nests where the eggs are protected until they hatch. These usually produce fewer eggs than those that make no provision for the care of their eggs. Some of the perch-like kinds and a few others retain the eggs in the body until they hatch, and thus produce living young.

Fish Culture.—Many of our best food-fishes occur in seemingly inexhaustible numbers. When we read of shoals of

fish extending over an area of six or eight square miles or of their being so thick in a stream that they completely fill it from bank to bank, or of their filling the nets and traps of the fishermen so full that they cannot be lifted, we can hardly believe that the time will come when the supply will not meet the demand. Yet when we consider that we sometimes take 3,000,000,000 herring, and more than 455,000,000 pounds of salmon, and 75,000,000 pounds of white fish in one season, and other kinds of fish in corresponding numbers, it seems evident that the supply will not always last, especially as by far the greatest number of these fish are taken while they are on their way to their spawning beds or after they have just reached them. Indeed, many of our most profitable fisheries would have been ruined long before this if the state and national governments had not come to their aid, and by more or less effective laws stopped some of the needless slaughter, and, especially, by artificial propagation, increased the supply.

We are accustomed to say that nature's way of doing a thing is the best way, but this is not always so by any means. When the female king salmon leaves the ocean, swims far up some stream and reaches her spawning bed, she hollows out a little place in the gravel and deposits her eggs which scatter over the bottom. Many of them settle in crevices where they are safe, but others are left exposed, attractive morsels for the hungry trout and other fish which haunt the spawning beds. Soon after the female has laid her eggs the male deposits close to them the milt, which contains the spermatozoa. Probably a large percentage of the eggs are fertilized. They remain in their hiding places for about two months, unless disturbed by freshets. Finally the young salmon issues and after about two months more of waiting, during which time it is absorbing the yolk sac which furnishes it its food, it ventures forth to seek other food. Most of these young salmon fall a prey to the larger fish and other enemies before they are old enough to be able to take care of themselves. Thus from the thousands of eggs that are laid by the parent salmon comparatively few young issue and live long enough to make their perilous journey back to the sea.

This is nature's way, and it is a wasteful one, yet enough fish were produced each year to maintain the species in great numbers. But when the demand of man for fish became so great that, hundreds, and later, thousands of men devoted their time and energies to catching salmon wherever possible, it was found that the number of fish was fast decreasing. Under these conditions, the government established hatcheries along some of the rivers where the salmon naturally spawned.

On these spawning beds the salmon are taken by means of traps or nets, and, if the eggs are ripe, the body of the female is held over a pan and gently pressed so the eggs will flow out into the water in the pan. The milt from the male is procured in the same way, and is poured over the eggs, thus fertilizing them. The eggs are then taken to the hatchery, where they are placed in wire baskets which are lowered into troughs of flowing water and kept until the young fish hatch and have absorbed the yolk sac and are able to take care of themselves. In this way 80 per cent. to 95 per cent. of the eggs that are taken are saved, and millions of young fish are turned into the streams from the hatcheries that are located along the tributaries of many of the most important salmon rivers.

This is surely a great improvement over nature's wasteful methods. In this way the fisheries on the Sacramento and Columbia rivers have been maintained, whereas otherwise they would have long ago been depleted. Other salmon hatcheries have been established in Washington, British Columbia and Alaska, until now provision is made for caring for the eggs of all of the species of salmon, especial attention being paid to the king, or chinook, and the red, or sockeye, salmon, as these are commercially the most important

In the same way the eggs of many species of trout are taken and hatched, and the young turned directly into streams or lakes, or kept in ponds where they can be fed and reared. At certain stages of their development the eggs can be packed and shipped long distances, or the young may be carried shorter distances in cans if the water is kept well aerated. Thus many barren streams and lakes can be stocked with choice varieties of

trout or the supply may be increased in the regions where too constant fishing has depleted the numbers.

With certain modifications of this general plan, necessitated by the structure and habits of the fish, the black and striped bass, the whitefish, shad, pike, codfish, mackerel and others are also artificially propagated in great quantities.

The federal government now operates thirty-six permanent hatcheries, besides nearly a hundred auxilliary stations. In these more than forty species of the best food and game fishes are handled. These hatcheries are distributed over thirty-three states, and some of these states themselves maintain other hatcheries which handle even more fish than the government hatcheries. New methods and improved appliances are constantly being adopted, wonderfully increasing the usefulness of these establishments. In this way the United States Bureau of Fisheries and the various State Fish Commissions are doing a valuable work in economic zoology and one that can be appreciated by all citizens. The same Bureau and Commissions are at work also on similar problems in connection with the lobster, oyster, crab, shrimp, clam, mussel and other invertebrate animals that are considered as a part of our fishery resources.

Classification.—The class *Pisces* may be divided into four sub-classes, namely: the *Elasmobranchii*, including the sharks, skates, torpedoes, etc.; the *Holocephali*, including the chimaeras, a few strange-bodied forms; the *Teleostomi*, including nearly all of the other fishes, as the sturgeons, catfish, bass, salmon, trout, cod, mackerel, herring, etc.; and the *Dipneusti*, or lung-fishes, represented by only a few genera whose members have lungs in addition to gills.

The Sharks, Skates and Ray (sub-class *Elasmobranchii*).—These differ from the bony fishes in several important respects, and some icthyologists raise the sub-class to the rank of a class. They have a skeleton composed of cartilage, there is no operculum, and no true scales. Their teeth are distinct, often large and highly specialized. All the members of the group are marine.

The fierce, carnivorous and voracious sharks live in the

surface waters and feed on any other animals that they can capture. The shark's mouth is on the underside of the head, so it must turn over on its back in order to sieze any prey that is swimming above it. The great basking sharks, genus *Cetorhinus*, which reach a length of nearly forty feet, often gather in numbers and float motionless on the surface of the sea. The great white shark, *Carcharodon carcharias*, occurs

FIG. 114.—The common skate, *Raja erinacea*. (From Kingsley.)

in all warm seas, and because it does not hesitate to attack man it is often known as the man-eating shark. It attains a length of thirty feet or more. The smooth dogfish shark, *Mustelus*, the horned dogfish shark, *Squalus*, and the sand-shark, *Carcharias*, often occur in great numbers in shallow waters and do much damage by destroying lobsters and many valuable food fishes. They are a great nuisance on the

fishing grounds not only on account of the fact that they kill but because they drive away the schools of fish and squid and destroy the nets and traps.

The skates and rays have a broad, flattened body with the gill-openings on the underside. They are usually sluggish, lying at the bottom of shallow waters along the shore feeding on crabs, molluscs and bottom fishes. The small common skates, or "tobacco-boxes," *Raja erinacea*, which reach a length of about twenty inches, and the larger "barn-door skates," *R. lævis*, are numerous along the Atlantic Coast. The sting-rays, genus *Dasyatis*, which lie in the sand in shallow water, have a barbed spine on their whip-like tail which makes a very painful wound. The torpedoes, or electric-rays, have, on either side of the head, modified bundles of muscles which store up considerable electric energy. The discharge from these electric organs can give a strong shock to animals coming in contact with them. It is said that a discharge from a large electric-ray is sufficient to disable a man temporarily. The saw-fish, *Pristis pectinatus*, differs from the typical rays by having the body more elongate and shark-like. The head is prolonged into a long saw-like snout which may reach a length of five feet or more. This may be used as a weapon of defense or to kill the small sardines and herring upon which the saw-fishes feed.

The Chimæras, or "Elephant Fishes" (sub-class *Holocephali*).—These fishes compose a small group of peculiar forms looking somewhat like the smaller sharks. Most of them live in deep water, but others are rather common in the shallow water of bays along both coasts of America and elsewhere. They are of very little economic importance.

The True Fishes (sub-class *Teleostomi*).—To this sub-class belong nearly all of our common fishes, both of fresh water and ocean. In most of them the skeleton is bony and not cartilaginous as in the sharks and rays. The sturgeons, family *Acipenseridæ*, are the notable exception to this rule, as their skeleton is cartilaginous. In the garpikes and a few others the skeleton is only partly bony. The sturgeons occur in both salt and fresh water, some of them attaining a weight

of 300 to 500 pounds or more. The skin is provided with series of large bony plates on the sides, on the back and beneath. These plates are not contiguous, and so do not form a complete covering for the body. Although the meat is rather coarse it is largely used for food, and the egg masses, or roe, are used in making caviar. Some of the largest species, such as those that run up into the Columbia, were almost exterminated by wanton destruction before the need of conserving them was realized.

The garpikes, family *Lepisosteidæ*, are common in the lakes and rivers of the middle and eastern United States. They are long and slender, and the body is covered with close-set horny scales which form a complete armor. They are carnivorous and often destroy great numbers of valuable food fishes, they themselves being unfit for food.

The catfishes, family *Siluridæ*, are distinguished by their smooth skin, which is without scales, and by the somewhat flattened head and the numerous long, soft, slender feelers about the mouth. There are many kinds known by different common names, such as "horned pout," "bull-head," "channel-cat," etc. The latter sometimes reaches a weight of 200 pounds. Most of them are excellent food fishes.

The suckers, family *Catostomidæ*, occur abundantly in almost all regions. They feed on insects and small aquatic animals which they suck up into their mouth. Some reach a length of about three feet, but their flesh is flavorless and full of bones, so they are but little used for food.

The family *Cyprinidæ* includes the carps, chubs, minnows and gold fishes. One of the most common carps, *Cyprinus carpio*, commonly known as the European carp, is a native of China, where it has been domesticated for centuries. About 300 years ago it was introduced into Europe and later into the United States where its cultivation has attracted considerable attention. They are not generally prized as food fish by Americans, but are largely used by other nationalities and so are important fish in many of the larger markets. The chubs (*Notropis* spp.) are abundant in nearly all fresh water, and sometimes reach considerable size, but they are of little value as food. Many of the smaller species belonging to this

family are known as *minnows*. They are an important source of food for larger fish, and are much used for bait.

The goldfish, *Carassius auratus*, is a native of China. In its native waters or where it escapes from domestication it is of a greenish hue, the beautiful golden yellow color being brought about and retained by artificial selection. In the same way the many strange shapes and varieties have been produced.

The true eels, family *Anguillidæ*, are long, slender and with small inconspicuous scales. They are found in most fresh water streams and lakes where they feed chiefly on all kinds of refuse, but they frequently destroy great numbers of shad, herring and other fish, particularly at spawning time. They go down the rivers to the sea to spawn. The ova are very minute, and it has been estimated that a single female may produce over 10,000,000 eggs. They are regarded as excellent food fishes.

The conger-eels, family *Leptocephalidæ*, are scaleless, occur in the sea at moderate depths, and are little used as food in America.

The family *Clupeidæ* includes the herring, sardines, shad, menhaden and others. The herring, genus *Clupea*, occur in both the Atlantic and Pacific, and when they come in shore at spawning time they are taken in great numbers and canned as sardines, dried, smoked or salted, or used fresh for food or bait. The herring fisheries of the North Atlantic are particularly important. It has been estimated that at least 10,000,000,000 herring are taken by British and American fisherman each year representing a weight of more than one-third as many pounds. They occur in great shoals sometimes miles in extent.

The sardines (genus *Sardinella*) are fine-flavored little fish with rather soft bones. Preserved in oil they form a most important article of commerce. Great numbers are used for bait.

The shad (genus *Alosa*), although very bony, are highly esteemed on account of their fine delicate flavor. They occur on both coasts, having been introduced into California, and ascend the rivers to spawn in May. They are very prolific,

each female yielding usually about 30,000 eggs, but some have been known to produce two or three or even five times as many.

Although the menhaden (genus *Brevoortia*) are but little valued for food, they are of great commercial importance on account of the oil that is extracted from them. The refuse is used for fertilizer. They are also largely used in the preparation of fish meal for domestic animals.

The anchovies, family *Engraulidæ*, are fine-flavored oily little fish that are often preserved in oil or spices. They are very abundant in many waters, and form an important source of bait and of food for other fishes.

In many respects the family *Salmonidæ*, including the salmon, trout, and whitefish, is the most important of all. The salmon fisheries constitute one of the principal industries of the Pacific northwest, the whitefish are among the most important fish of the Lake regions, and the trout are found in almost all swift-flowing streams and clear cold lakes, and are more sought after by the angler than any other fish.

The Pacific salmon, genus *Oncorhynchus*, occur in the north Pacific. Little is known of their habits while in the sea, but just before spawning time they enter certain rivers and start upstream for the spawning grounds, taking no food while in fresh water. The king salmon, or quinnat salmon, enters, in enormous numbers, such rivers as the Sacramento, Columbia, Frazer and Yukon, large streams fed by mountain snows. Up these rivers they may make their way through rapids and over falls for several hundred miles, often to the very head waters, before spawning. In the Yukon they may ascend 2250 miles from the ocean.

The red salmon, or sockeye salmon, is commercially the most important of all. They are taken in large seines or traps in Puget Sound or similar bays while going in great schools to the rivers which they ascend to reach their spawning grounds. They will enter only such rivers as are fed by lakes, and spawn in the small streams that flow into the lakes, sometimes 1000 to 1800 miles from the ocean. The other species spawn closer to the sea in almost any fresh water stream. After spawning, the salmon remain near their eggs until, too weak to resist

the current, they drift down and die. Most of the young make their way to the sea and a few return, three or four years later, as mature fish ready to spawn. The salmon fisheries have long been one of the most important industries on the Pacific Coast. In some years more than 5,000,000 cases are packed, each case containing forty-eight one-pound cans. The value of such a pack is more than $25,000,000.

The Atlantic Coast salmon, *Salmo salar*, ascend fresh water streams to spawn, but unlike the western salmon, they return alive to the sea again.

There are many species of trout, as the black-spotted, rainbow and cut-throat, belonging to the genus *Salmo*. Many

FIG. 115.—The rainbow-trout, *Salmo irideus*.

of these species are represented by one or more varieties, so it is often difficult for even an expert ichthyologist to determine the species definitely. There are certain well-marked types, however, and each region has its particular representative trout type which affords the best kind of sport to the enthusiastic anglers. The genus *Salvelinus* includes some of the choicest and most beautiful of the brook trout. They are frequently called char, and differ from the members of the genus *Salmo* in that the body is covered with round crimson or gray spots which are paler than the ground color. The scales are smaller and so imbeded in the skin as generally to escape notice.

The whitefish, genus *Coregonus*, occurring usually in clear cold lakes or streams, are regarded as especially fine food

fishes. The largest of the species of this genus ranges from New York and the Great Lakes northward. The whitefish constitute the most imporant group of the fresh water fishes. While the average weight is probably under four pounds some attain a weight of more than twenty pounds. Although considerable quantities are salted the largest part of the catch, valued some years at more than $1,500,000, is used fresh.

The lake herring, genus *Argyrosomus*, are closely related to the whitefish, but are not as highly valued as food. They occur in enormous numbers throughout the Great Lake region.

The grayling, family *Thymallidæ*, beautiful, trout-like fish, found in some of our northern streams and common in Europe, are characterized by the greatly developed dorsal fin. They are superior food and game fishes.

The smelt, family *Argentinidæ*, are also closely related to the *Salmonidæ*. They are mostly marine, and all are excellent food fishes. The eulachon, or candle-fish, is regarded by many as the most delicate and luscious of all fishes. They are very oily and it is said that when dried and provided with a wick they will burn like a candle. The oil is pressed out and used to some extent as a substitute for cod-liver oil.

The pike, family *Esocidæ*, are long, slender, swift-swimming fish found in many fresh water lakes and streams, the fine muskallunge of the Great Lake region reaching a weight of sixty to eighty pounds. The smaller pike are sometimes called pickerel. They are all excellent food and game fishes.

The mullets, family *Mugilidæ*, are found in both fresh and salt water, where they feed on the organic matter that they can sift out of the mud. In some regions they are especially abundant, particularly along the Florida and Gulf coast where they are important food fishes.

The mackerel, family *Scombridæ*, are among the most important fishes of the Atlantic. Along the New England coast many villages are almost wholly dependent upon the success attained by the crews of the fleets of splendid mackerel schooners that each season put out to fish. Hundreds of thousands of barrels of mackerel are salted each year, and great quantities are used fresh. Several species occur along the

Atlantic and Pacific Coasts and in many other parts of the world. Some of the species, such as the Spanish mackerel and the tuna, are unexcelled as food or game fishes.

The large family *Centrarchidæ* includes the sunfishes and rock bass, black bass and others. The various species of sunfishes occur in almost all parts of the country. Some of them are handsomely marked and they are all good food fishes. The black bass are among the most important of the game fishes, and are fast taking the place of the trout in many streams where the latter have not been able to hold their own on account of the changed conditions of the water and the intensive fishing. The bass quickly adapt themselves to their surroundings and have been successfully introduced into California, Europe and other places where they do not occur naturally. The fresh water white bass and yellow bass, and the larger striped bass or rock-fish which lives in the sea and runs up the rivers to spawn, and many other important sea bass, belong to the family *Serranidæ*. The giant bass, sometimes called jewfish, reaches a weight of more than 500 pounds.

The family *Percidæ* includes the wall-eyed pike and the true perches of which the yellow perch is our most common example. They are both good game and food fishes.

On the west coast is a family of perch-like ocean fishes, family *Embiotocidæ*, commonly called perch or surf-fish. These differ from almost all of the other higher fish in being viviparous, the young being carried in the body of the mother until they have attained considerable size.

The codfish, family *Gadidæ*, is one of the most important of the North Atlantic fishes. It occurs also in the North Pacific but in small numbers. The codfish industry gives employment to thousands of men and warrants a profitable investment in boats and other apparatus to the extent of millions of dollars. The flesh of the cod is flaky and with little flavor but it is well adapted to drying or salting and it is in this condition that it is most largely used.

Among the most remarkable of our well-known fishes are the flounders and halibut, family *Pleuronectidæ*. The young at first swim upright in the water like other fishes and have

their eyes in the normal position. But soon they begin to rest on the bottom and the eye on the lower side begins to migrate, so that in a little while both eyes are close together on the upper side of the head. Many species of flounders and soles are found along the shores of both oceans. They are largely used as food. The halibut occur on offshore banks in the northern part of the Atlantic and Pacific oceans. They reach a length of six to eight feet and a weight of 500 pounds or more. The halibut fisheries are very important, especially in the north Pacific. The young halibut, called "chicken halibut," are tender and of fine flavor, differing in this

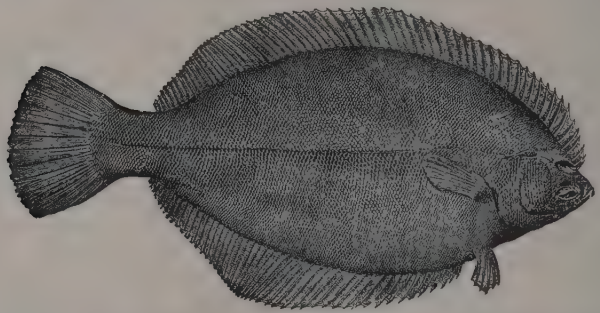


FIG. 116.—The winter flounder, *Pseudopleuronectes americanus*. (After Goode.)

respect from most of the flat fishes which, although in great demand for food, do not have much flavor.

With this brief review of only a few of the more important of the many hundreds of common food or game fishes we must leave the discussion of this sub-class without even a reference to the many strange and interesting fishes that occur in the fresh waters of other lands and in other seas. Among the coral reefs that surround many of the tropical islands are to be found most beautifully colored fishes; in the greatest depths of the ocean are strange uncanny fish, some of which are provided with phosphorescent patches on their heads or on appendages, enabling them to see in the dark abysses. For the study of these

and such others as the curious sea-horses and the remarkable flying-fish, and the fishes that leave the water and wander over the land, the student must go to some of the detailed works on fishes, as Jordan's "Guide to the Study of Fishes." Jordan & Evermann's "American Food and Game Fishes" is a most excellent treatise, popular enough so that anyone may enjoy reading it.

The Lung-fishes (sub-class *Dipneusti*).—This sub-class, formerly called *Dipnoi*, is represented by only a few living species, occurring in Australia, South America and Africa. They are of particular interest to the naturalist not only because they are the sole survivors of a once numerous group of fishes, but because several things about their structure seem to indicate that they must be closely allied to the ancestral type from which both the bony fishes and the Amphibia, or frogs, salamanders, etc., have descended. The gills in most of them remain functional and are used while the animals are in the water, but at other times, when they burrow into the wet mud or elsewhere, they breathe by means of lungs, which are spongy sacs, represented in most fishes by the air bladder. The paired fins, too, have an elongated jointed axis with rays which resemble the limbs of some of the Amphibia as much as the fins of fish.

CHAPTER XXII

TOADS, FROGS AND SALAMANDERS

The toads and frogs are the most common representatives of the class *Amphibia*, but the salamanders, or water-dogs, are very often found along streams or in moist places. The cœcilians, legless, worm-like or snake-like creatures occurring in the tropics, also belong to this class.

Almost fifteen hundred living species of amphibians are known. These may be grouped into three fairly well-defined orders, the *Apoda*, or footless, snake-like forms, the *Urodela*, or tailed amphibians, and the *Anura*, or tailless forms like the toad and frog.

The Cœcilians (order *Apoda*).—This order includes a few worm-like or snake-like footless species called cœcilians usually having small scales embedded in the skin. They occur only in tropical regions and are of no economic importance.

The Water-dogs (order *Urodela*).—Several widely different forms are grouped together in this order so that it is often divided into suborders. They all agree in having a tail, which may be longer or shorter than the rest of the body. The mud-puppies or water-dogs, genus *Necturus*, occur in the rivers and lakes of the northern United States. They attain a length of about two feet when full grown. They have four legs, and breathe by means of bushy gills which arise from in front of the forelegs. The sirens or mud-eels, genus *Siren*, burrow in the mud in ponds and ditches in the southern states, attaining a length of about three feet. They have three pairs of gills and only one pair of legs.

The large, heavy-bodied, blackish water-dog or hell-bender, genus *Cryptobranchus*, is another aquatic form, but the external gills are replaced by small openings or gill slits which lead into the throat. It is found along the Ohio river

and its tributaries. The salamanders and newts are common in many regions. Most of them possess neither gills nor gill openings in the adult. Some of them are often called lizards, but they differ widely from the lizards in many respects. The body is soft and not provided with scales, and in their development they pass through a tadpole stage similar to that of the frogs and toads. *Amblystoma tigrinum* is an interesting and widely distributed common species. In some regions the larval form, known as axolotl, reaches a large size and produces young before completing the usual metamorphosis.

FIG. 117.—A brown salamander, *Notophthalmus torosus*. (Reduced.)

The Frogs and Toads (order *Anura*).—This is by far the largest and most important order of *Amphibia*. There are about a dozen species of frogs, family *Ranidæ*, found in the United States. The well known bullfrog, *Rana catesbiana*, is the largest of these, attaining a length of seven or eight inches. It occurs in ponds and sluggish streams all over the eastern United States and in the Mississippi Valley. Frogs are very commonly used as food in the United States but not as extensively as in some of the European countries. The large hind legs and "saddle" afford a considerable mass of very delicately flavored meat. It has been pointed out that there is an opportunity for the development of a small but profitable industry in raising frogs for market in some of the extensive

areas of marsh land where frogs abound. Frogs are used more than any other vertebrate in the laboratories of schools and colleges, not only because they are easily obtained but because in their structure and habits one may find illustrations of so many of the fundamental facts of zoology. The tree-frogs or tree-toads, family *Hylidæ*, are more closely related to the toads than to the frogs. Their toes are usually provided with adhesive disks which enable them to cling to the trunk of a tree or other perpendicular surfaces. Their vocal sacs are

FIG. 118.—A western garden toad, *Bufo halophilus*. (Reduced.)

large, and they make a noise out of all proportion to their size. *Hyla versicolor*, the most common of these tree-frogs, is green, gray or brown above, and has the power of slowly changing from one color to another so as to produce a remarkable harmony between the frog and its surroundings, thus making it almost invisible to its enemies. This change in color is brought about by the expansion or contraction of certain pigment cells in the skin.

The structure and habits of the toads, family *Bufonidæ*, have already been discussed (Chapter II). There are about fifteen species in the United States and less than one hundred species in other lands. Some of the exotic species

are interesting on account of the unusual method of caring for their eggs or young. The females of some species carry the eggs on their back until they hatch. Others are provided with a large pouch in which all the eggs are stored, or with a cell-like pouch for each egg where the larva hatches and remains until it has passed through the tadpole stage. In still other species the male cares for the eggs. All toads are beneficial because they eat so many noxious insects.

The Frog Book, by Mary Dickerson, gives an admirable account of the kinds, distribution and habits of the American frogs and toads. It is well illustrated in color.

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CHAPTER XXIII

SNAKES, LIZARDS, TURTLES, AND CROCODILES

The large class, *Reptilia*, including the turtles and tortoises, crocodiles and alligators, lizards and snakes, is composed of animals differing in general appearance but possessing many characteristic features that show their close relationship. Most of them are terrestrial in habitat. All are cold blooded and almost all breathe by means of lungs, those that spend part of their life in water coming to the surface to breathe. Nearly all creep or crawl, dragging the body on the ground or close to it. The body is covered with scales or with large plates. The reptiles pass through no metamorphosis during their development, the young when born or hatched from the egg resembling the adult except in size. Most reptiles lay eggs, as do the birds, and so are called *oviparous*. But the common garter-snakes and some other species retain the eggs within the body until they are hatched, and so are said to be *ovoviparous*. The eggs are usually laid in the earth or sand or in vegetable mould and given no further care by the mother, but some species show great solicitude for the eggs, guarding them jealously until they hatch.

In general appearance some of the lizards resemble the salamanders and other amphibians more than they do other members of their own class, and the reptiles are usually closely associated in the common mind with the amphibians. A study of their body structure, however, shows that they are really more closely related to the birds than to the amphibians. In some of the extinct orders of reptiles the resemblance to birds was quite remarkable from the fact that their whole body was modified to fit them for flight. Some of these flying reptiles, the *Pterosauria*, attained a great size, having a wing expanse of twenty feet. But that was during the Cretaceous epoch, or

Age of Reptiles, when the giant Dinosaurians, some of which measured over a hundred feet in length, roamed the swamps, and the whale-like Ichthyosaurians swam in the seas.

In reptiles, as in amphibians, the chief variations in the body skeleton are correlated with differences in external body form. In the short compact body of the turtles and tortoises the number of vertebræ is much smaller than in snakes. Some turtles have only 34 vertebræ; certain snakes as many as 400. The reptilian skull, in the number and disposition of its parts and in the manner of its attachment to the spinal column, resembles that of the birds, although the cranial bones remain separate, not fusing as in birds. All of the reptiles, except the turtles, are provided with small teeth which serve, generally, for seizing or holding prey and not for mastication.

Reptiles breathe solely by lungs, of which there is a pair. They are simple and sac-like, the left lung being often much smaller than the other. In turtles and crocodiles the lungs are divided internally by septa into a number of chambers. Because of the rigidity of the carapace, or "box", of turtles the air cannot be taken in the ordinary way by the use of the ribs and rib muscles, but has to be swallowed. The reptilian heart consists of two distinct auricles and of two ventricles, which in most reptiles are only incompletely divided, the division into right and left ventricles being complete only among the crocodiles and alligators, the most highly organized of living reptiles.

The organs of the nervous system reach a considerable degree of development in the animals of this class. The brain in size and complexity is plainly superior to the amphibian brain and resembles quite closely that of birds. Of the organs of special sense those of touch are limited to special papillæ in the skin of certain snakes and many lizards. Taste seems to be little developed, but olfactory organs of considerable complexity are present in most forms, and consist of a pair of nostrils with olfactory folds on their inner surfaces. The ears vary much in degree of organization, crocodiles and alligators being the only reptiles with a well-defined outer ear. This consists of a dermal flap covering a tympanum,

Eyes are always present and are highly developed. They resemble the eyes of birds in many particulars. All reptiles, except the snakes and a few lizards, have movable eyelids, including a nictitating membrane like that of the birds. With the snake the eye is protected by the outer skin, a transparent portion of which remains intact over the eye. Turtles and lizards have a ring of bony plates surrounding the eyes similar to that of birds. In addition to the usual eye there is in many lizards a remarkable eye-like organ, the so-called pineal eye, which is situated in the roof of the cranium, and is believed to be the vestige of a true third eye, which in ancient reptiles was probably a well-developed organ.

Classification.—The living reptiles may be divided into four orders. One of these, the order *Rhynchocephalia*, includes only a single lizard-like genus confined to New Zealand. The *Chelonia*, including the turtles and tortoises, are distinguished by the scaly, bony or leathery shell covering the body. The *Crocodilia*, or crocodiles and alligators, have the body covered with rows of sculptured horny scutes or scales, while the lizards and snakes, order *Squamata*, are usually covered with many small, flat, horny, epidermal scales.

Turtles and Tortoises.—The short stout body of these animals is enclosed in a more or less firm shell, which consists of an upper portion, the *carapace*, that is firmly joined along the sides to the lower portion, the *plastron*. From the front opening of this box-like covering the head and forelegs may be protruded when the animal is feeding or moving about, the hind legs and tail being extended from the opening along the posterior margin. When the appendages are withdrawn they fit snugly into these openings and the whole animal is comparatively safe from its enemies. In some turtles the shell does not become hard and horny, but remains soft or leathery. The head usually terminates in a hooked beak and serves as a formidable weapon of offense or defense. Many of the turtles are wholly aquatic, feeding on fish, frogs, worms, molluscs and sometimes small water-fowl or upon the grasses that grow in the water. Others spend a part of their time on the land and part in the water while still others are wholly

terrestrial. The term turtle is usually applied to the aquatic forms, while the land forms are commonly known as tortoises. The name terrapin is applied to some of the kinds that are used for food. They all lay eggs, which may be deposited in the banks of the ponds, rivers or streams, or in the sand, where they are incubated by the sun's rays.

Turtles, tortoises and terrapins are of considerable economic importance as some of them are highly valued for food. Also the horny carapace of many species is very valuable, being

FIG. 119.—The giant land-tortoise of the Galapagos Islands, *Testudo* sp. (These tortoises reach a length of four feet; after Coleman.)

used extensively in the manufacture of combs and various ornaments. Among the common aquatic species found in the United States are the soft-shelled turtles, genus *Trionyx*. The flat leathery shell as well as the enclosed body are used for food. The animal defends itself viciously when attacked. The large snapping-turtle, *Chelydra serpentina*, that is found in so many of the streams and ponds east of the Rocky Mountains, defends itself principally by its powerful beak as its shell is too small to protect it completely. The southern alligator snapping-turtle, *Macrochelys lacertina*, often attains a weight of

more than 100 pounds. It is largely used for food. Care has to be exercised in handling live specimens for they are of ugly temper and bite severely.

The painted turtle or painted terrapin, *Chrysemys picta*, has the carapace beautifully marked and colored. It lives in ponds and sluggish streams, feeding on aquatic plants and any insects or small animals that it may find in the water.

The famous diamond-back terrapin, *Malacoclemmys palustris*, lives in the salt marshes along the Atlantic coast. These animals, once very abundant, are now comparatively rare because they have been so much hunted. The price has rapidly risen from a few cents apiece to five or six dollars.

Still more highly prized for food is the great green turtle, *Chelonia mydas*. This species is widely distributed in tropical seas and occurs as far north along the Atlantic Coast as the Carolinas. It lives on the roots of eel or turtle grass, and may attain a weight of 500 pounds or more.

The hawk's-bill turtle or tortoise-shell turtle, *Chelonia imbricata*, is the source of the beautiful tortoise shell of commerce. Its shell is made up of a series of shield-like plates. About eight pounds of the valuable dorsal shields are sometimes obtained from a single large turtle of tropical and subtropical oceans.

The leather-back turtle, *Sphargis coriacea*, is the largest of the turtles, attaining a length of six to eight feet and a weight of a thousand pounds. It lives in tropical and semi-tropical seas, going on land only to deposit its eggs. Both the fore and hind limbs are modified into broad flippers for swimming. It is not used for food.

The giant tortoises, genus *Testudo*, inhabiting some of the tropical islands, often weigh as much as 300 pounds and some of them are estimated to be more than 400 years old.

Alligators and Crocodiles.—The skin of the alligators is thick and tough and covered with horny scales. The legs are well developed, but the animal moves clumsily on land. The long, laterally compressed tail makes them powerful swimmers. There are only two species of alligators, one occurring in China, the other, *Alligator mississippiensis*, in the southern parts of

the United States. The American alligator may grow to be ten or twelve feet long, and is hunted for its skin which makes strong, beautifully marked leather that takes a fine polish. The wholesale slaughter of these animals for their skin has so greatly reduced their numbers that extinction is threatened unless measures are taken to protect them in certain preserves.

The crocodiles are more widely distributed than are the alligators. The American crocodile, *Crocodilus americanus*, is found in Florida, Mexico and South America. It differs from the alligator in having a longer, narrower head.

The African crocodile, *C. niloticus*, is a ferocious species often attacking man and is greatly feared by the natives of that continent. There are several other crocodile kinds in various parts of the world, some of them reaching a length of twenty feet or more. The skin of many of the species is used for leather.

The Indian gavial, *Gavialis gangeticus*, common in the Ganges, attains a length of twenty feet or more, and is reputed to feed on the bodies of children that are thrown into the river by the natives. Its natural food is fish. It is distinguished from the alligators and crocodiles by having a long slender snout.

Chameleons, Lizards and Snakes.—The order *Squamata* is divided into three sub-orders: the *Rhiptoglossi*, including the chameleons, the *Sauria*, including the lizards, and the *Serpentes*, including the snakes. The true chameleons differ from the other members of this order in several respects. The body is laterally compressed, the legs are long and slender, and the toes are grouped so that two of them are opposed to the other three. The tongue can be projected for a remarkable distance for capturing insects. Chameleons are of interest because of their power of rapidly changing their colors. The color is usually greenish, but under certain stimuli, such as light and temperature, the color may change to varied shades simulating the surrounding objects. This change of color is, seemingly at least, partially under control of the animal. None of the members of this sub-order occurs in America, but there is found in the southern states a beautiful green lizard, *Anolis principalis*,

that has the power of changing its color to a considerable degree and so is popularly called a chameleon.

The group of lizards is a very large one, the species being especially abundant in the tropics. The skin is covered with many small scales, and the legs are fitted for running, but the

FIG. 120.—A fence lizard, *Sceloporus occidentalis*.

body is usually dragged along the ground and not wholly lifted by the legs. The jaws are furnished with teeth. Lizards feed principally upon insects, and some of the species may be of considerable importance in controlling noxious forms. Although the lizards are often regarded as being poisonous

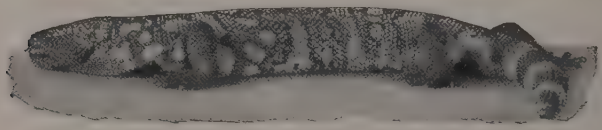

FIG. 121.—The Gila monster, *Heloderma suspectum*, the only poisonous lizard. (After Snyder.)

the members of only a single genus, *Heloderma*, are really so. This genus includes the Gila monster found in New Mexico, Arizona and northern Mexico. It is a heavy-bodied, deep black, orange-mottled lizard, twelve to sixteen inches long. The poison is secreted by glands in the lower jaw and flows

along the grooved teeth into the wound. The bite of this ill-looking reptile may be very serious.

The most common lizards in this country are the swifts and ground lizards that are so numerous in many gravelly and bushy places. They may often be seen sunning themselves on rocks, fences or other exposed places. They are all very timid. An interesting member of this group is the glass snake, or joint-snake. Having no external limbs it is commonly considered to be a snake rather than a lizard. Its tail is so brittle that part of it may break off at the slightest pull or blow. In time a new tail is regenerated. Many other lizards possess this power of easily breaking off a portion of the tail. It will be seen that this may often be of considerable importance to the lizard, for if it is pursued by an enemy the part most likely to be seized is the tail, and if this can be broken off the lizard may escape and in time the lost part be replaced.

In the desert regions of the Southwest are found several species of the peculiar little lizard commonly known as the horned toad, genus *Phrynosoma*. The body is shortened, much flattened, and furnished with a number of spine-like scales. These spines are particularly well-developed in a row along the hind margin of the head. The color of these animals resembles very closely the soil or rocks where they are found. This protecting coloration doubtless helps to save them from their enemies. In the tropics many of the lizards attain a great size, and are of strange shapes and patterns. Some of the tree-inhabiting forms are very beautifully colored. The iguanas in South America often reach a length of five or six feet, and are much used for food.

The appendages are entirely absent in most of the snakes. A few species, however, have a pair of spur-like projections on the hinder part of the body, doubtless vestiges of the hind legs. The lower side of the body in front of the anus is covered with broad scales, called abdominal *scutes*, which extend from one side of the body to the other. The ends of these broad scales are attached to the ribs, and the free posterior edges may be drawn forward slightly and pressed against the surface on which the snake is lying so that when they are

drawn back again the body of the snake is thrust forward. It is the movement of these scutes, accompanied by the undulations of the body, that enables the snake to crawl so rapidly. They cannot move forward on smooth surfaces because the scutes have nothing to catch against. The scales on the head are quite regular in their arrangement, forming definite patterns. The bones of the jaws are so arranged that the mouth is very distensible. This allows the snakes to swallow objects which are greater in size than the normal diameter of the body and it is not an unusual sight to see a

FIG. 122.—A garter-snake, *Thamnophis parietalis*. (After Snyder.)

snake with a part of its body very greatly distended by some small animal that it has swallowed whole. The tongue is slender, protrusible and deeply notched. It is commonly supposed that the tongue can inflict injury, but this is not true. It doubtless serves as a special organ of touch. The teeth are sharp and recurrent. In the poisonous snakes certain of the teeth develop into long sharp fangs which are grooved or tubular and serve to conduct the poison from the poison gland in the head into the wound. The food of snakes consists very largely of other animals which are usually caught alive. Many species feed on the eggs of other animals. Many persons erroneously regard all snakes as dangerous, and try to kill all that they see. But most of our common kinds are not only harmless but very serviceable because they destroy mice,

ground squirrels or other pests. The blind snakes, genus *Glauconia*, burrow in the earth and feed on insect larvæ and worms.

Among the most familiar of the many non-poisonous snakes are the striped garter-snakes, genus *Thamnophis*, found everywhere in the fields and gardens. The common water-snake, genus *Natrix*, is only semi-aquatic, spending most of the time on land in the vicinity of ponds or streams. They are excellent swimmers and quickly take to the water when alarmed. The large blacksnake, *Zamenis constrictor*, and the blue-racer,

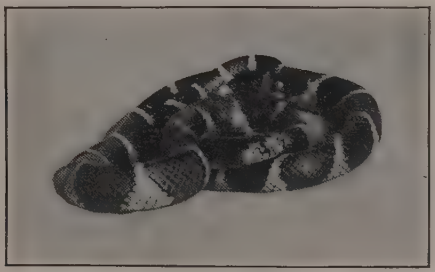

Fig. 123.—A king-snake, *Lampropeltis boyli*. (After Snyder.)

which is merely a color variety of the same species, are common in open meadows, where they feed on frogs, mice, eggs, young birds and other animals which they swallow alive. The king-snakes, genus *Ophibolus*, are so called because they feed on other snakes. They seem to be immune to the venom of the poisonous snakes and readily attack any of them. The puff-adders, or spreading vipers, or blow-snakes, genus *Heterodon*, are commonly supposed to be poisonous but are really quite harmless. No American snake with slender, sub-parallel-sided head is poisonous.

The dreaded rattlesnakes, and the copperheads and water-moccasins, are thick-bodied venomous snakes with flat, triangular heads and with strong tubular fangs which are folded flat against the roof of the mouth when it is closed. When

the snake strikes, these fangs are lowered and thrust into the victim and the poison, which is secreted by small glands in the head, is injected through them. There are several species of rattlesnakes, all belonging to the genus *Crotalus*. They are most abundant in the Southwest, but are found in almost all parts of the United States except in the higher mountains. The rattle on the tail is composed of a series of partly overlapping thin horny pieces, the somewhat modified successively formed epidermal coverings of the tip of the body. A new rattle is added each time the snake sheds its skin, and as the snakes usually molt about three times a year the age of a rattlesnake may be approximately estimated provided none of the terminal units of the rattle has been lost.

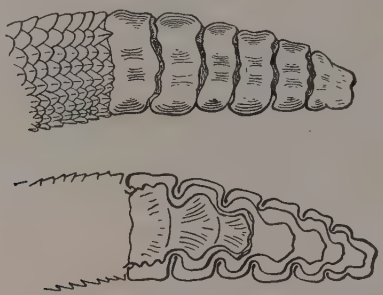

FIG. 124.—The rattles of the rattlesnake. The lower figure shows a longitudinal section of the rattle.

The chestnut-colored copperheads, *Agkistrodon contortrix*, occur throughout the eastern and middle United States. They are very vicious and dangerous, striking without warning. The water-moccasin, *Agkistrodon piscivoris*, of the southern states is the most dangerous of our serpents. It is found in swampy places and in the water. It is ill-tempered and aggressive, striking on the slightest provocation. The poisonous harlequins or coral-snakes, *Elaps fulvius*, that live in the southeastern United States, are also very venomous. They are black, very strikingly marked by broad, yellow-bordered, crimson rings.

Notwithstanding the fact that a bite from any one of these venomous snakes may prove fatal to man in a very short time, the real danger from these snakes is not as great as it would seem, for they may usually be seen or heard and avoided. The number of deaths resulting from snake bites in the United States each year is very small indeed, an average of but only two each year, it has been estimated. Sucking the blood and poison from the wound or drinking large quantities of whiskey are the two methods most commonly recommended for treating snake bites. Sucking the poison from the wound may do some good but it is very dangerous, for should some of the poison get into cuts or abrasions on the lips or in the mouth it might cause more harm that it would in the original wound. Excessive use of alcoholic drinks must also be avoided, as experiments have shown that they may exert a very unfavorable effect. The best thing to do if one should be bitten by a poisonous snake is to apply pressure, by a ligature or otherwise, to the blood-vessels leading from the wound to the heart to prevent the blood from carrying the poison to the heart. If a physician is not available within a very short time the tissue around the wound should be incised deeply and a solution of potassium permanganate (1 part of the chemical to 100 parts of water) injected. If properly and promptly applied such a treatment may destroy much of the venom before it can reach the heart and be sent from there over the whole system. Hypochlorite of calcium, 1 part to 60 parts of water, or chloride of gold, 1 to 100, or chromic acid, 1 to 100, may be used if the potassium permanganate is not available. When the venom of a poisonous snake is introduced into the blood of an animal in small quantities it is capable of pro-

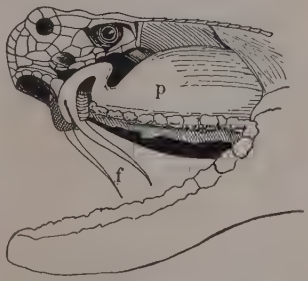

FIG. 125.—Dissection of head of rattlesnake. *f*, poison-fangs; *p*, poison-sac.

ducing a substance called antivenin which neutralizes the effect of that particular kind of poison. In regions where snake bites are of frequent occurrence the antivenin for the most dangerous snakes is prepared and kept ready for use. A small amount of it injected into the blood-vessels soon after a snake has bitten a person usually counteracts the effects of the venom. Most dangerous of all the poisonous snakes is the dreaded cobra of India, *Naja tripudians*, a very vicious and most deadly reptile. Twenty-five to 55 per cent. of cobra bites prove fatal, and the annual loss of human lives in India from this snake is often over 20,000. The sea-snakes, which inhabit many tropical seas, attaining a length of six or eight feet, are also very poisonous. The body is often compressed thus better fitting them for their aquatic life. They do not leave the water even to breed, but give birth to their living young while at sea.

The pythons, genus *Python*, which sometimes attain a length of twenty or thirty feet, and the smaller boas or boa-constrictors, *Boa constrictor*, are not venomous. They kill their prey by coiling their body around it and crushing it. These are tropical or semi-tropical snakes.

CHAPTER XXIV

BIRDS

The birds, class *Aves*, the most familiar and attractive of wild animals, have been the object of so much attention and study by professional naturalists, amateur nature students and just nature lovers, that their classification, life history and habits are better known than are those of any other animal group.

About 12,000[1] different species of birds are known from all the world, of which about 800 occur in North America. In any single favorable locality in this country one can get acquainted with from 100 to 200 species, counting in those kinds that pass in the fall and spring migrations as well as those that nest in the locality. The number of kinds that may be called "all-year residents," that is, which remain in the same region through the whole year, is, however, very small, averaging usually about one-seventh of the total number that may be seen in the region during the course of a year. This limited number of kinds of birds in any one locality, together with the bright colors and characteristic manners which make their identification easy, the interest of their songs and flight and their feeding, nesting and general domestic habits, make birds excellent subjects for personal field studies by students. And if the food habits are studied from an economic point of view, valuable practical information can be obtained during the study.

General Structure.—The general body form and external appearance of a bird are too familiar to need description. The covering of feathers, the modification of the fore limbs

[1] The British Museum Catalogue lists nearly 19,000 species but it recognizes as full species about 7000 forms considered by most ornithologists to be merely varieties or sub-species.

into wings, and the toothless, beaked mouth are characteristic and distinguishing external features. The feathers, although covering the whole of the surface of the body, are not uniformly distributed, but are grouped in tracts called *pterylæ*, separated by bare or downy spaces called *apteria*. They are of several kinds, the short soft plumules, or down feathers, the large, stiffer, contour feathers, whose ends form the outermost

FIG. 126.—A body feather and a wing feather from a chicken. (Reduced.)

covering of the body, the quill feathers of the wings and tail, and the fine bristles, or vibrissæ, about the eyes and nostrils, called thread feathers. The fore limbs are modified to serve as wings, which are well developed in almost all birds. However, the strange kiwi, or *Apteryx*, of New Zealand with hair-like feathers is almost wingless, and the penguins have the wings so reduced as to be incapable of flight, but serving as flippers to aid in swimming underneath the water. The

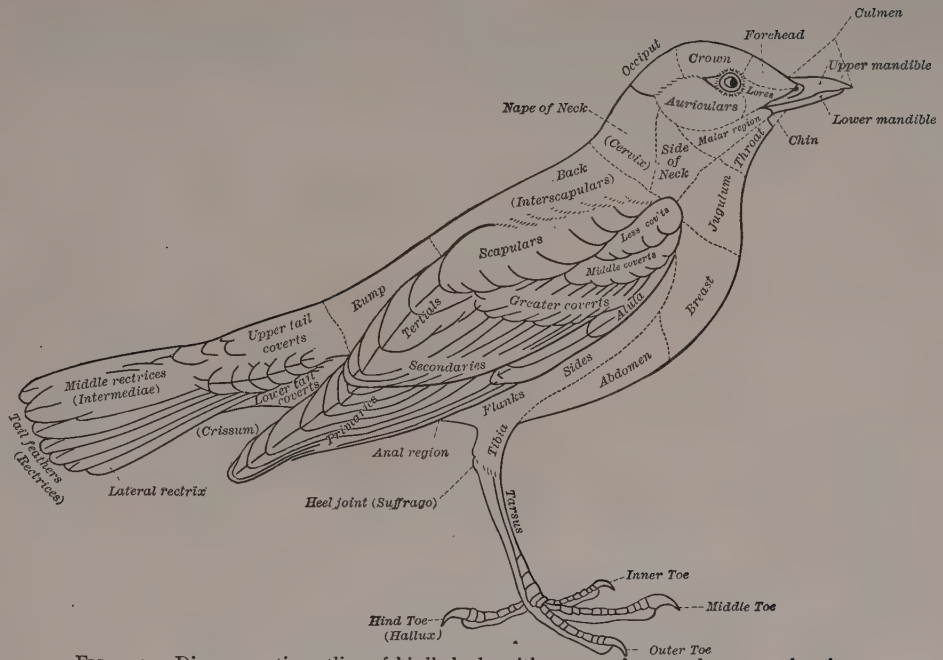

FIG. 127.—Diagrammatic outline of bird's body with names of external parts and regions.

ostriches and cassowaries also have only rudimentary wings and are not able to fly. Legs are present and functional in all birds, varying in relative length, shape of feet, etc., to suit the special perching, running, wading, or swimming habits of the various kinds. Living birds are toothless, although certain extinct forms, known through fossils, had on both jaws large teeth set in sockets. The place of teeth is taken, as far as may be, by the bill or beak formed of the two jaws, projecting forward and tapering more or less abruptly to a point. In most birds the jaws or mandibles are covered by a horny sheath. In some water and shore forms the mandibular covering is soft and leathery. The range in size of birds is indicated by comparing a humming-bird with an ostrich.

Many of the bones of birds are hollow and contain air. The air-spaces in them connect with air-sacs in the body, which connect, in turn, with the lungs. Thus a bird's body contains a large amount of air. The breastbone is usually provided with a marked ridge or keel for the attachment of the large and powerful muscles that move the wings, but in those birds like the ostriches, which do not fly and have only rudimentary wings, this keel is greatly reduced or wholly wanting. The fore limbs or wings are terminated by three "fingers" only. The legs have usually four toes, although a few birds have only three toes and the ostriches but two.

As birds have no teeth with which to masticate their food, a special region of the alimentary canal, the gizzard, is provided with strong muscles and a hard and rough inner surface by means of which the food is crushed. Seed-eating birds have the gizzard especially well developed, and some birds take small stones into the gizzard to assist in the grinding. The lungs of birds are more complex than those of amphibians and reptiles, being divided into small spaces by numerous membranous partitions. They are not lobed, as in mammals, and do not lie free in the body cavity, but are fixed to the inner dorsal region of the body. Connected with the lungs are the air-sacs already referred to, which are in turn connected with the air-spaces in the hollow bones. By this arrangement the bird can fill with air not only its lungs but all the special air-sacs

and spaces. The special function of these air-sacs in not understood; many believe that in some way they aid the bird in its flight or in respiration. The vocal utterances of birds are produced by the vocal cords of the syrinx or lower larynx, situated at the lower end of the trachea just where it divides into the two bronchial tubes, the tracheal rings being here modified so as to produce a voice-box containing two vocal cords controlled by five or six pairs of muscles. The air passing through the voice-box strikes against the vocal cords, the tension of which can be varied by the muscles. In mammals the voice-organ is at the upper or throat end of the trachea.

The heart of birds is composed of four distinct chambers, the septum between the two ventricles, incomplete in the *Reptilia*, being complete in this group. There is thus no mixing of arterial and venous blood in the heart. The systemic blood circulation being completely separated from the pulmonic, the circulation is said to be double. The circulation of birds is active and intense; they have the hottest blood and the quickest pulse of all animals. In them the brain is compact and large, and more highly developed than in amphibians and reptiles, but the cerebrum has no convolutions as in the mammals. Of the special senses the organs of touch and taste are apparently not keen; those of smell, hearing, and sight are well developed. The optic lobes of the brain are of great size, relatively, compared with those of other vertebrate brains, and there is no doubt that the sight of birds is keen and effective. The power of accommodation, or of quickly changing the focus of the eye, is highly perfected. The structure of the ear is comparatively simple, there being ordinarily no external ear, other than a simple opening. The organs of the inner ear, however, are well developed, and birds undoubtedly have excellent hearing. The nostrils open upon the beak, and the nasal chambers are not at all complex, the smelling surface being not very extensive. It is probable that the sense of smell is not, as a rule, especially keen.

Development and Life History.—All birds are hatched from eggs, which undergo a longer or shorter period of incubation outside the body of the mother, and which are, in most cases,

laid in a nest and incubated by the parents. The eggs are fertilized within the body of the female, the mating time of most birds being in the spring or early summer. Some kinds, the English sparrow, for example, rear numerous broods each year, but most species have only one or at most two. The eggs vary greatly in size and color-markings, and in number from one, as with many of the Arctic ocean birds, to six or ten, as with most of the familiar song-birds, or from ten to twenty, as with some of the pheasants and grouse. The duration of incubation (outside the body) varies from ten to thirty days among the more familiar birds, to nearly fifty among the ostriches. The temperature necessary for incubation is about 40° C. (100° F.). Among polygamous birds (species in which a male mates with several or many females) the males take no part in the incubation and little or none in the care of the hatched young; among most monogamous birds, however, the male helps to build the nest, takes his turn at sitting on the eggs, and is active in bringing food for the young, and in defending them from enemies. The young, when ready to hatch, break the egg-shell with the "egg-tooth," a horny, pointed projection on the upper mandible, and emerge either blind and almost naked, dependent upon the parents for food until able to fly (*altricial* young), or with eyes open and with body covered with down, and able in a few hours to feed themselves (*precocial* young).

Classification.—The class *Aves* is usually divided into numerous orders, the number and limits of these as published in zoological manuals varying according to the opinions of various zoologists. The rank of an order in this group is far lower than in most other classes. In other words, the orders are very much alike and are recognized mainly for the convenience in breaking up the vast assemblage of species. In North America most of the ornithologists have agreed upon a scheme of classification, which will therefore be adopted in this book. This classification, together with a complete catalogue of all North American bird kinds, is published by the American Ornithologists Union as a "Checklist of North American Birds." According to this classification the 800

(approximately) known species of North American birds represent seventeen orders. Certain recognized orders, for example, the ostriches, are not represented naturally in North America at all.

Ostriches.—The old order *Ratitæ* (now divided into several smaller orders) or birds without keeled breastbone, as the

FIG. 128.—Ostriches on ostrich farm at Pasadena, California.

ostriches, cassowaries, rheas, etc., is not represented naturally in this country, but in California, Arizona, Florida, and a few other states, the African ostrich, *Struthio camelus*, is being bred and reared on "ostrich farms" for the sake of its plumes. This is the largest living kind of bird, specimens attaining the height of eight feet and the weight of 300 pounds. The

eggs, which are five to six inches long and nearly as thick, are laid naturally in shallow hollows scooped out in the sand of the desert, and the hot sun and the male birds do most of the incubating. The young hatch in from seven to eight weeks, and can run about immediately.

Ostriches used to be hunted and killed for their feathers, but since the discovery that they can be reared in confinement and a superior quality of plumes thus obtained, their hunting has been given up. They have been domesticated in South Africa since about 1865, and now about half a million tame birds exist there. The present annual value of the ostrich plume output is about $10,000,000. Good average birds will produce $50 worth of feathers a year, and are worth from $700 to $1000 a pair. The plumes grow on the rudimentary wings and tail, and the plucking does not hurt the birds in any way.

Water and Shore Birds.—The typical water birds include the order *Pygopodes*, or loons, grebes, auks, etc.; the *Longipennes*, or gulls, terns, petrels and albatrosses; the *Steganopodes*, or cormorants, pelicans, and boobies; and the *Anseres*, or swans, geese and ducks. Among these the cormorants and gulls are of some special use to man as scavengers along the seashore, the gulls especially doing much to rid harbors of refuse thrown overboard by the ships. But it is among the *Anseres* especially that are found the water birds that interest the economic zoologist particularly. The order includes about sixty North American species, of which three are swans, sixteen geese, and the rest ducks. In all, the bill is more or less flattened and is also lamellate, *i.e.*, furnished along each cutting edge with a regular series of tooth-like ridges. The feet are webbed and the legs short and set far back on the body, an adaptation for effective swimming. The food consists of roots and seeds of plants, worms, insects, small molluscs and even small fishes, and only in occasional instances, as in the invasion of grain fields by geese, are the food habits likely to cause loss to man.

On the other hand, both geese and ducks are among our most abundant and largest game birds, and certain species, such as

the Canada goose and the mallard, teal, pintail, widgeon, shoveller or spoonbill, canvasback, redhead, bluebill and other ducks, provide not only sport, but very enjoyable food during the shooting season. Of these perhaps the most notable are the mallard, which is primarily a fresh water duck and is the ancestor of most of our domesticated races, and the canvasback, a salt water species especially abundant from Chesapeake Bay south along the Carolina Coast, and on the whole, more prized for its flavor than any other duck. The special flavor of the east coast canvasback may be due to its feeding largely on wild celery (*Vallisneria*). To the uneducated palate, however, the milder-flavored fresh water or river ducks will be more enjoyable than the canvasbacks, redheads and bluebills of the coast waters.

The wading and shore birds include the order *Herodiones*, or ibises, herons and bitterns, the *Paludicolæ*, cranes, rails and coots, and the *Limicolæ*, comprising the plover, curlew, sandpipers and snipes. These orders include numerous game birds such as the rails, woodcock, jacksnipe, various plovers, curlews, yellowlegs and sandpipers. In rare instances cranes may invade grain fields, but the food of most of the waders is obtained from the marshes or bay and lake shores, and consists chiefly of small animals, running all the way from frogs down to insects. The rails, however, have a fondness for seeds, especially wild rice, and the clapper rail and sora, or Carolina rail, become very fat in the autumn and are much hunted in the marshes of the South Atlantic States. The woodcock frequents thick brush and covert in the Eastern States and lies there concealed in daytime, issuing at dusk to search for food on marshy ground. It is thus rather owl-like in habit and with its big head and eyes is indeed rather owl-like in appearance except of course for its long bill and snipe's legs. Its flesh is highly esteemed, but in the absence of suitably protecting game laws it has been so ruthlessly shot for market that it is already a vanishing species. The jacksnipe, or Wilson's snipe, common over the whole country, is one of the best known of game birds. It is a swift, erratic flyer, and frequents open marshy ground. The golden plover is a special

favorite for its flesh but it has been so persistently shot that its numbers have been greatly lessened.

The Pheasants and Doves (Orders *Gallinæ* and *Columbæ*).—The *Gallinæ* include most of the domestic fowls, as the hen, turkey, peacock and guinea fowls. They include also the chief game birds of most countries, as the grouse, quail, partridges, wild turkey, ptarmigan, etc. They all have the bill rather

FIG. 129.—The common Eastern quail, or Bob-white, *Colinus virginianus*. (Photograph by J. M. Slonaker.)

short, heavy, convex and bony, adapted for picking up and crushing seeds and grains which compose their principal food. They are mostly terrestrial in habit and are sometimes known as the *Rasores*, or "scratchers." The eggs are numerous, and are laid in a rude nest or simply in a depression on the ground. In many of the species polygamy is the rule. The young are precocial. Among the more familiar wild gallinaceous birds

are the eastern quail, or "bob-white," abundant in the eastern and central United States, the ruffed grouse of the eastern woods, and the prairie chicken of the western prairies. Besides the bob-white there are five other quail species in this country, all of which live in western and especially southwestern regions. The examination of many stomachs has shown that more than 50 per cent. of the food of all these quail is weed seeds. The rest is composed of insects, some grains, and a miscellany comprising leaves, buds, spiders, myriapods, crustaceans, etc. The bob-white eats about 83½ per cent. vegetable matter and 16½ per cent. animal matter. As the weed seeds and insects together compose the major part of the food, quails are far more beneficial than hurtful to the farmer.

The doves and pigeons constitute the small order *Columbæ*, closely related to the *Gallinæ*. The bill is covered at the base by a soft swollen membrane, or cere, in which the nostrils open. The food consists of fruits, seeds and grains. The most familiar wild species is the mourning dove, or turtle dove, which occurs all over the country, and is shot as a game bird in some states. The beautiful passenger pigeon, formerly extremely abundant, moving about in enormous flocks in the eastern and central states, has been exterminated by ruthless killing. All the various kinds of domestic pigeons such as pouters, fantails, carriers, ruff-necks, tumblers, etc., are believed to be the modified descendants of the common European rock dove, *Columba livia*.

Other Land Birds.—Of the other land birds, besides the *Gallinæ* and *Columbæ*, about one-half belong to the order *Passeres*, or perching birds. The others are distributed among the orders *Raptores*, or birds of prey, *Pici*, or woodpeckers, *Coccyges*, or cuckoos and kingfishers, *Macrochires*, or whip-poorwills, chimney-swifts and humming-birds, and the *Psittaci*, or parrots, of which but one species, the small Carolina parroquet, exists wild, in small numbers, in the United States. It is found only in Florida.

The *Raptores* include the eagles, hawks, vultures and owls, and their food habits make them on the whole decidedly beneficial birds. Of the fifty or more species of eagles and hawks

found in this country only a few kinds ever raid barnyards or pastures, while the same kinds, together with all the others, make way with many noxious rodents and large insects, such as grasshoppers, crickets and June bugs. Their captures of other birds are, however, mostly to be deplored, and two species of small hawks, Cooper's hawk and the sharp-shinned hawk,

FIG. 130.—Red-headed woodpecker, *Melanerpes erythrocephalus*, young at opening of nest to receive food from the mother. (Photograph by J. M. Slonaker.)

deserve to be shot on sight, for they feed almost entirely on wild birds and poultry.

There are twenty-three species of woodpeckers in the United States, and the food of twenty of them consists chiefly of insects, usually wood-boring grubs. These birds do much good by destroying many insect pests of trees. But there are three kinds, with short brushy tongues not adapted to

the capture of insects, which do some injury to trees by feeding on the live bark and sap of trees. More than two hundred and fifty kinds of trees, shrubs and vines are attacked by these sap-suckers. They are especially fond of and, hence, hurtful to hickory trees. The common sap-sucker of the western states is the only woodpecker in that region that has the whole head and throat red, while the common one of the middle and eastern states is the only one having the front of the head from bill to crown red and a black patch on the breast. By these marks these two injurious woodpeckers can be distinguished from the others, all of which are beneficial.

The *Passeres* include the familiar song birds and the great majority of the birds of the garden, the forest, the roadside and the field. The feet of these birds always have four toes and are fitted for perching. The syrinx, or musical apparatus, is well developed in most of them. Nesting and domestic habits are various, but the young are always hatched in a helpless condition, and have to be fed and otherwise cared for by the parents for a longer or shorter time. The North American species of this order are grouped into eighteen families, as the fly-catcher family (*Tyrannidæ*), crow family (*Corvidæ*), the sparrows and finches (*Fringillidæ*), the swallows (*Hirundinidæ*), the thrushes, robins and blue birds (*Turdidæ*), etc. In this small book nothing can be said of the various species which belong to this order. However, as the Passerine birds are those which immediately surround us and which, by their familiar songs and nesting habits, most interest us, the outdoor study of birds by beginning students will usually be devoted chiefly to the members of this order, and many different kinds will soon become familiar. The robin and blue bird will introduce us to their shy and familiar relatives, the song thrushes; the study of the king bird or bee-martin will interest us in some of the other fly-catchers. From the familiar chipping sparrow and tree-sparrow we shall be led to look for their cousins the swamp-sparrows and the larger grosbeaks and crossbills, and so on through the order.

Determining and Studying the Birds of a Locality.—To identify the various species of birds in the locality of a school

it will be necessary to have some book giving the descriptions of all or most of the species of the region, with tables and keys for tracing out the different forms. Such bird manuals and keys are numerous now, as, because of the popular interest in bird study, many bird books have been published in the last few years. The best general manual is Coues' "Key to the Birds of North America" (5th ed., 2 vols.). Chapman's "Handbook of the Birds of Eastern North America," and Florence Bailey's "Handbook of Birds of Western United States," are each complete for the regions covered by them. There are other books that attempt to make it possible by keys based chiefly on color and pattern differences to distinguish the birds without having their dead bodies actually in hand, which usually means shooting the bird. There are several magazines devoted to accounts of the life and habits of birds. Of these "Birdlore" is the organ of the Audubon Society for the Protection of Birds, and is an accurate but popular and beautifully illustrated journal. Fig. 127 will aid the student in the use of any of these bird books by making him acquainted with the names of the various external parts and special plumage regions of the bird's body.

Birds and Seasons.—In trying to become acquainted with the birds of a locality it must be borne in mind that the bird-fauna of any region varies with the season. Some birds live in it all the year through; these are called *residents*. Some spend only the summer or breeding season in the locality, coming up from the South in spring and flying back in autumn; these are *summer residents*. Some spend only the winter in the locality, coming down from the severer North at the beginning of winter, and going back with the coming of spring; these are *winter residents*. Some are to be found in the locality only in spring and autumn, as they are migrating north and south between their tropical winter quarters and their northern summer or breeding home; these are *migrants*. And, finally, an occasional representative of certain bird species, whose normal range does not include the given locality at all, will appear now and then, blown aside from its regular path of migration, or otherwise astray; these are *visitants*. As to

the relative importance, numerically, of these various categories among the birds which may be found in a certain region, and thus form its bird-fauna, we may illustrate by reference to a definite region. Of the 351 species of birds which have been found in the state of Kansas (a region without distinct natural boundaries, and fairly representative of any Mississippi valley region of similar extent), 51 are all-year residents, 125 are summer residents, 36 are winter residents, 104 are migrants, and 35 are rare visitants.

FIG. 131.—Nest of song sparrow, *Melospiza cinerea*. (Photograph by J. H. Paine)

The all-year residents and the summer residents, comprising about one-half of the species to be found in a locality, are the only ones which breed there, and which thus present opportunity for observations on their nest-building habits and care of the young. Numerous suggestive questions present themselves in connection with breeding. Why is it that some species nest early and some late? Can the character of the food of the young have anything to do with this? If so, what? Does the condition of the particular trees, bushes or other favorite sites for nests help determine the nesting time? Why

should some birds raise but one brood a year, and others two or even three? Does the fact that a bird is an all-year resident or only a summer resident have any influence in determining its nesting time and the number of broods it rears? Compare the habits of the various breeding species of the locality, and find out if the summer residents have any breeding habits in common as distinguished from the all-year residents.

Observe the behavior of the birds in courting time. Do the males have "singing contests," as is sometimes reported? Do they fight with each other? Do the males or females show any differences, at this time, from their more usual plumage? After mating which bird selects the nesting site? Are old nesting sites preferred to new ones? If two broods are reared is a new nest built for the second one? What are the principal causes of mortality among the eggs and young during the breeding season? What instincts or habits of the parents have direct reference to these dangerous conditions? What means of protecting the nest are resorted to? What is the behavior of the parents toward enemies of the young?

Distribution and Migration.—The geographical distribution of animals is a subject of much importance, and offers good opportunities in its more local features for student field-work. The field-study of the birds of a given locality will comprise much observation bearing directly on zoogeography, or the distribution of animals. Certain birds will be found to be limited to certain parts of even a small region; the swimmers will be found in ponds and streams, and the long-legged shore birds on the pond- or stream-banks, or in the marshes and wet meadows, although a few, like the upland-plover, curlews, and godwits are common on the dry upland pastures. Distinguish the ground birds of the shrubs and hedge-rows, and these again from the strictly forest birds. Find the special haunts of swallows and king-fishers. Which are the shy birds driven constantly deeper into the wild places, or being exterminated by the advance of man? Which birds do not retreat, but even find an advantage in man's seizure of the land, obtaining food from his fields and gardens?

Make a map on large scale of the locality of the school,

showing on it the topographic features of the region, such as streams, ponds, marshes, hills, woods, springs, wild pastures, etc., also roads and paths, and such landmarks as school-houses, country churches, etc. On this map indicate the local distribution of the birds, as determined by the data gradually gathered; mark favorite nesting-places of various species, roosting-places of crows and black-birds, feeding-places, and bathing- and drinking-places of certain kinds, the exact spots of finding rare visitants, rare nests, etc.

As already mentioned, many of the birds of a locality are "migrants," that is, they breed farther north, but spend the winter in more southern latitudes. These migrants pass through the locality twice each year, going north in the spring and south in the autumn. They are much more likely to be observed during the spring migration than in the fall, as the flight south is usually more hurried. The observation of the migration of birds is very interesting, and much can be done by beginning students. Notes should be made recording the first time each spring a migrating species is seen, the time when it is most abundant, and the last time it is seen the same spring. Similar records should be made showing the movements of the birds in the fall. A series of such records, covering a few years, will show which are the earliest to appear, which the later and which the last. Such records of appearance and disappearance should also be kept for the summer residents, those birds that come from the south in the spring, breed in the locality, and then depart for the south again in the autumn. Notes on the kinds of days, as stormy, clear, cold, warm, etc., on which the migration seems to be most active; on the greater prevalence of migratory flights by day or by night; on the height from the earth at which the migrants fly, etc., are all worth while. For an excellent simple account of migration see Chapman's "Bird-Life," Chapter IV. A more detailed account of migration, and one giving the records for many species at many points in the Mississippi Valley, is Cooke's "Bird Migration in the Mississippi Valley."

Plumage.—It must be kept in mind in using bird-keys and descriptions to determine species that the descriptions and

keys refer to adult birds, and in ordinary plumage. Among numerous birds the young of the year, although old enough to fly and as large as the adults, still differ considerably in plumage from the latter; males differ from females, and finally both males and females may change their plumage (hence color and markings) with the season. The seasonal changes of plumage accomplished by molting may be marked or hardly noticeable. "All birds get new suits at least once a year, changing in the fall. Some change in the spring also, either partially or wholly, while others have as many as three changes —perhaps, to a slight extent, a few more. . . . It is claimed by some that now all new colors are acquired by molt, and by others that in some instances (young hawks) an infusion or loss, as the case may be, of pigment takes place as the feather forms, and continues so long as it grows."

There is much lack and uncertainty of knowledge concerning the molting and change of plumage by birds, and careful observations by bird students should be made on the subject.

For accounts of the plumage and color of birds see Chapter III in Chapman's "Bird-Life" and Chapters VIII and IX in Baskett's "Story of the Birds."

Structure and Habit.—In connection with learning the different kinds of birds in a locality, observations should be made, and notes of them recorded, on their habits, and on their external structure and its relation to the habits of the bird. The interesting adaptation of structure to special use is particularly well shown in the varying character of the bill and feet of birds. The various feeding habits and uses of the feet of different birds are readily observed, and the accompanying modification of bills and feet can be readily seen in birds preserved as "bird-skins." In some cases the general structure of feet and bills may be seen in the live birds by the use of an opera-glass. The characters of bills and feet are much used in the classification of birds, so that any knowledge of them gained primarily in the study of adaptations will have a secondary use in classification work.

Note the foot of a robin, bluebird, catbird, wren, warbler, or other Passerine or perching bird. It has three unwebbed toes

in front and a long hind toe perfectly opposable to the middle front one. This is the perching foot. Note the so-called zygodactyl foot of the woodpecker, with two toes projecting in front and partly yoked together, and two similarly yoked projecting behind. Note the webbed swimming foot of the aquatic birds; note the different degrees of webbing, from the toti-palmate, where all four toes are completely webbed, palmate, where the three front toes only are bound together but the web runs out to the claws, to the semi-palmate, where the web runs out only about halfway. Note the lobate foot of the coots and phalaropes. Note the long, slender, wading legs of the sandpipers, snipe, and other shore-birds; the short, heavy, strong leg of the divers; the small weak leg of the swifts and humming-birds, almost always on the wing; the stout, heavily nailed foot of the scratchers, as the hens, grouse, and turkeys; and the strong, grasping talons, with their sharp, long, curving nails, of the hawks and owls, and other birds of prey. In all these cases the fitness of the structure of the foot to the special habits of the bird is apparent.

Similarly the shape and structural character of the bill should be noted, as related to its use, this being chiefly concerned of course with the feeding habits. Note the strong, hooked, and dentate bill of the birds of prey; they tear their prey. Note the long, slender, sensitive bill of the sandpipers; they probe the wet sand for worms. Note the short, weak bill and wide mouth of the night-hawk and whippoorwill, and of the swifts and swallows; they catch insects in this wide mouth while on the wing. Note the flat, lamellate bill of the ducks; they scoop up mud and water and strain their food from it. Note the firm, chisel-like bill of the woodpeckers; they dig into hard wood for insects. Note the peculiarly crossed mandibles of the cross-bills; they tear open pine cones for seeds. Note the long, sharp, slender bill of the humming-birds; they get nectar and insects from the bottom of flower-cups. Note the bill and foot of any bird you examine, and see if you can recognize their special adaptation to the habits of the bird.

The most casual observation of birds reveals differences in the flight of different kinds so characteristic and distinctive

as to give much aid in determining the identity of birds in nature. Note the flight of the woodpeckers; it identifies them unmistakably in the air. Note the rapid beating of the wings of quail and grouse; also of wild ducks; the slow, heavy, flapping of the larger hawks and owls, and of the crows; and the splendid soaring of the turkey-buzzard and of the gulls. This soaring has been the subject of much observation and study, but is still imperfectly understood. The soaring bird evidently takes advantage of horizontal air-currents, and some observers maintain that upward currents also must be present. The speed of flight of some birds is enormous, the passenger-pigeon having been estimated to attain a speed of one hundred miles an hour. The long distances covered in a single continuous flight by certain birds are also extraordinary, as is also the total distance covered by some of the migrants. The differences in the structural character of the wings should be noted in connection with the observation of the differences in flight habit. The tongue and tail of birds are two other structures the modifications and special uses of which may be readily observed and studied. Note the structure and special use of the tongue and tail of the woodpeckers; note the tongue of the humming-bird; the tail of the grackles.

Feeding Habits, Economics, and Protection of Birds.—The feeding habits of birds have been already repeatedly referred to. The study of these habits is not only interesting but is, of course, of much importance in that it is the character of these habits that determines the economic relation of birds to man, that is, whether a particular bird species is harmful or beneficial. Casual observation shows that birds eat worms, grains, seeds, fruits, insects. A single species often is both fruit-eating and insect-eating. Do fruits or do insects compose the chief food-supply of the species? To determine this more than casual observation is necessary. The birds must be watched when feeding at different seasons. The most effective determinations of the kind of food taken by various birds has been based on examinations of the stomach of many individuals taken at various times and localities. Much work of this kind has been done, especially by investigators

connected with the Bureau of Biological Survey of the United States Department of Agriculture, and pamphlets giving the results of these investigations can be had from the Superintendent of Public Documents, Washington, D. C. The food habits of over 400 species of native birds and of several introduced kinds are referred to in these publications. Full reports based on stomach investigations have been made on the food of 173 native species. As a result of all this work it has been clearly shown that a great majority of birds are chiefly beneficial to man by eating noxious insects and seeds of weeds. Most birds commonly reputed to be harmful, and for that reason shot by farmers and fruit-growers, have been proved to do much more good than harm. An investigation of the food habits of the crow, a bird of ill-repute among farmers, based on an examination of 909 stomachs, show that about 29 per cent. of the food of the year consists of grain, of which corn constitutes something more than 21 per cent., the greatest quantity being eaten in the three winter months. All of this must be either waste grain picked up in fields and roads, or corn stolen from cribs and shocks. May, the month of sprouting corn, shows a slight increase over the other spring and summer months. On the other hand, the loss of grain is off-set by the destruction of insects. These constitute more than 23 per cent. of the crow's yearly diet, and the larger part of them are noxious. The remainder of the crow's food consists of wild fruit, seeds, and various animal substances which may on the whole be considered neutral. However, some few birds have been proved to be, on the whole, harmful.

The slaughter of birds for millinery purposes has become so fearful and apparent in recent years that a strong movement for their protection has been inaugurated. Rapacious egg-collecting, legislation against birds wrongly thought to be harmful to grains and fruits, and the selfish wholesale killing of birds by professional and amateur hunters, help in the work of destruction. Apart from the brutality of such slaughter, and the extermination of the most beautiful and enjoyable of our animal companions, this destruction works strongly

against our material interests. Birds are the natural enemies of insect pests, and the destroying of the birds means the rapid increase and spread, and the enhanced destructive power of the pests. It is asserted by investigators that during the past fifteen years the number of our common song-birds has been reduced by one-fourth. At the present rate, says one author, extermination of many species will occur during the lives of most of us. Already the passenger-pigeon and Carolina paroquet, only a few years ago abundant, are practically exterminated. In Japan and Italy there are hardly any song-birds left so ruthless has been their destruction. We do not want to come to that condition. Protect the birds!

CHAPTER XXV

MAMMALS

Although by no means the largest numerically, the class of mammals, *Mammalia*, is by far the most important group of animals. Not only does it include man himself but practically all of the domestic animals besides scores of others that add to his welfare by furnishing him food or clothing. The name *Mammalia* refers to the mammary glands of the female which furnish milk for the nourishment of the young for some time after its birth.

In size, the mammals range from the tiny pigmy-shrew of fields and meadows to the great whales which attain a length of eighty to a hundred feet and a weight of many tons. In structure and habits there is also a remarkable range of variation. Most mammals live on land and their legs are usually well fitted for walking, running or jumping, but some live in trees and have their appendages adapted for holding on to the branches or for taking considerable leaps through the air. Others, like the burrowing gophers and moles, live in the earth and have the forelegs fitted for digging. The water-inhabiting forms often have their appendages modified into fins or flippers and in other ways show remarkable adaptations fitting them for their aquatic life.

Body-form and Structure.—Most mammals are clothed with hairs, which are peculiarly modified epidermal processes. Each hair, usually cylindrical, is composed of two parts, a central pith containing air, and an outer more solid cortex; each hair rises from a short papilla sunk at the bottom of a follicle lying in the true skin. In some mammals the hairs assume the form of spines, or "quills," as in the porcupine. The hairy coat is virtually wanting in whales and is very sparse in certain other forms, the elephant, for example,

which has its skin greatly thickened. The claws of beasts of prey, the hoofs of hoofed mammals, and the outer horny sheaths of the hollow-horned ruminants are all epidermal structures.

The bones of mammals are firmer than those of other vertebrates, containing a larger proportion of salts of lime. Among the different forms the spinal column varies largely in the number of vertebræ, this variation being chiefly due to differences in length of tail. Apart from the caudal vertebræ their usual number is about thirty. The mammalian skull is very firm and rigid, all the bones composing it, excepting the lower jaw, the tiny auditory ossicles, and the slender bones of the hyoid arch, being immovably articulated. The correspondence between the bones of the two sets of limbs is very apparent. The number of digits varies in different mammals, and also in the fore and hind limbs of a single species. Among the Ungulates, or hoofed animals, the reduction in the number of digits is especially noticeable; the forefoot of a pig has four digits, that of the cow two, and that of the horse one. The two short "splint" bones in the horse are remnants of lost digits. The teeth are important structures in mammals, being used not only for tearing and masticating food, but as weapons of offense and defense. A tooth consists of an inner soft pulp (in old teeth the pulp may become converted into bone-like material) surrounded by hard white dentine, or ivory, which is covered by a thin layer of enamel, the hardest tissue known in the animal body. A hard cement sometimes covers as a thin layer the outer surface of the root, and may also cover the enamel of the crown. The teeth in most forms are of three groups: (a) the incisors, with sharp cutting edges and simple roots, situated in the center of the jaw; (b) the canines, often conical and sharp-pointed, next to the incisors; (c) then the molars, broad and flat-topped for grinding, and divided into premolars and true molars. There is great variety in the character and arrangement of the teeth in mammals, their variations being much used in classification.

The mouth is bounded by fleshy lips. On the floor of the mouth is the tongue, which bears the taste-buds or papillæ,

the organs of taste. The esophagus is always a simple straight tube, but the stomach varies greatly, being usually simple, but sometimes, as in the ruminants and whales, divided into several distinct chambers. The intestine in vegetarian animals is very long, being in a cow twenty times the length of the body. In the carnivores it is comparatively short—in a tiger, for example, but two or three times the length of the body.

The blood of mammals is warm, having a temperature of from 35° C. to 40° C. (95° F. to 104° F.). It is red in color, owing to the reddish-yellow, circular, non-nucleated blood-corpuscles. The circulation is double, the heart being composed of two distinct auricles and two distinct ventricles. Air is taken in through the nostrils or mouth and carried through the windpipe (trachea) and a pair of bronchi to the lungs, where it gives up its oxygen to the blood, from which it takes up carbon dioxide in turn. At the upper end of the trachea is the larynx, or voice-box, consisting of several cartilages attaching by one end to the vocal cords and by the other to the muscles. By the alteration of the relative position of these cartilages the cords can be tightened or relaxed, brought together or moved apart, as required, to modulate the tone and volume of the voice.

The kidneys of mammals are more compact and definite in form than those of other vertebrates. In all mammals except the Monotremes (duckbills, etc.), they discharge their product through the paired ureters into a bladder, whence the urine passes from the body by a single median urethra. Mammary glands, secreting the milk by which the young are nourished during the first period of their existence after birth, are present in both sexes in all mammals, though usually functional in the female only.

The nervous system and the organs of special sense reach their highest development in the mammals. In them the brain is distinguished by its large size, and by the special preponderance of the forebrain, or cerebral hemispheres, over the mid- and hind-brain. Man's brain is many times larger than that of any other known mammal of equal bulk of body, and three times as large as that of the largest-brained ape. In

man and the higher mammals the surface of the forebrain is thrown into many convolutions; among the lowest the surface is smooth. Of the organs of special sense, those of touch consist of free nerve-endings or minute tactile corpuscles in the skin. The tactile sense is especially acute in certain regions, as the lips and end of the snout in animals like hogs, the fingers in man, and the under surface of the tail in certain monkeys. All the other sense-organs are situated on the head. The organs of taste are certain so-called taste-buds located in the mucous membrane covering certain papillæ on the surface of the tongue. The organ of smell, absent only in certain whales, consists of a ramification of the olfactory nerves over a moist mucous membrane in the nose. The ears of mammals are more highly developed than those of other vertebrates both in respect to the greater complexity of the inner part and the size of the outer part. A large outer ear for collecting the sound-waves is present in all but a few mammals. A tympanic membrane separates it from the middle ear in which is a chain of three tiny bones leading from the tympanum to the inner ear, which is composed of the three semi-circular canals and the spiral cochlea. The eyes have the structure characteristic of the vertebrate eye, consisting of a movable eyeball composed of parts through which the rays of light are admitted, regulated, and concentrated upon the sensitive expansion, called retina, of the optic nerve lining the posterior part of the ball. The eye is protected by two movable lids. In almost all mammals below the Primates (man and the monkeys) there is a third lid, the nictitating membrane. In some burrowing rodents and others the eye is quite vestigial and even concealed beneath the skin.

The mental qualities of animals reach their highest development among the mammals. In the wary and patient hunting for prey by the carnivora, the gregarious and altruistic habits of the herding hoofed mammals, the highly developed and affectionate care of the young shown by most mammals, and in the loyal friendship and self-sacrifice of dogs and horses in their relations to man, we see the culmination among animals of the development of the functions of the nervous system.

In the characteristics of intelligence and reason, man, of course, stands immensely superior to all other animals, but both intelligence and reason are too often shown by many of the other mammals not to make us aware that man's mental powers differ only in degree, not in kind, from those of other animals.

Development and Life History.—All animals except the Monotremes give birth to free young. The Monotremes produce their young from eggs hatched outside the body. The embryo of other mammals develops in the lower portion of the egg-tube, to the walls of which it is intimately connected by a membrane called the *placenta*. (In the kangaroos and opossums, *Marsupialia*, there is no placenta.) Through this placenta blood-vessels extend from the body of the mother and from the embryo, and a close connection between the vascular systems of the parent and the embryo thus becomes established. In this way the developing young derives its nourishment from its mother.

The duration of gestation (embryonic or prenatal development in the mother's body) varies from three weeks with the mouse, eight weeks with the cat, nine months with the cow, to twenty months with the elephant. Like the birds, the young of some mammals, the carnivores, for example, are helpless at birth, while those of others, as the hoofed animals, are very soon able to run about. But all are nourished for a longer or shorter time by the milk secreted by the mammary glands of the mother.

Classification.[1]—The mammals are usually divided into eleven orders, eight of which occur in North America. The small order *Monotremata* includes but three species of primitive mammals, each representing a separate genus. They are found in Australia, Tasmania and New Guinea. Their most unusual and primitive characteristic is that of laying eggs. After hatching from the eggs the young are nourished on milk which does not issue from teats, but is poured out over the

[1] The classification adopted here is that used by Hornaday in his American Natural History. While later authorities have changed many of the scientific names, especially those of genera, the ones here used are the most familiar and hence the most useful.

hair of the abdomen and licked off by the young. The duck-bill or platypus, genus *Ornithorhynchus*, is about sixteen inches long, has webbed feet, close water-proof fur, and a flattened duck-like bill. It lives mostly in water, with an underground chamber leading from the water, in which the eggs are laid and the young reared. The spiny ant-eater, genus *Echidna*, lives in burrows, and feeds, by means of a long snout bearing the toothless mouth and extensile tongue, on ants. Its eggs are carried in a skin pouch on the abdomen.

The order *Marsupialia* includes the kangaroos, opossums, and others. These differ from all other mammals in that the female has an external pouch, or marsupium, in which the young are placed after birth and carried about and nourished until they are more fully developed. As these animals have no placenta, by means of which the young may be nourished by the blood of the mother, they are born in a very helpless condition and so must be cared for in the marsupium for some months. In Australia most of the land animals are marsupials. The kangaroos are the most familiar examples. They were formerly quite abundant, but have been hunted for their skins to make leather for shoes until their numbers have been much reduced. The opossum, *Didelphys virginiana*, which is the only North American representative of the order, lives in trees, is about the size of a common cat, and has a dirty-yellowish woolly fur. Its tail is long and scaly, like a rat's. Its food consists chiefly of insects, although small reptiles, birds, and bird's eggs are often eaten. When ready to bear young the opossum makes a nest of dried grass in the hollow of a tree, and produces about thirteen very small (half an inch long) helpless creatures. These are then placed by the mother in her pouch. Here they remain until two months or more after birth. Probably all the North American opossums found from New York to California and especially common in the Southern States, belong to a single species, but there is much variety among the individuals. They are commonly used for food and are sometimes seen on the market.

The order *Edentata* includes the sloths, armadillos and ant-eaters, all found in tropical regions. The sloths dwell in the

tree tops feeding on green leaves. They are not entirely toothless as the name of the order would indicate, but they are nearly so. "One cannot look at a live sloth without thinking that nature has but poorly equipped this animal to live in this murderous world. Its countenance is a picture of complete and far-reaching stupidity, its bodily form the acme of four-footed helplessness. It can neither fight, hide, nor run away. It has no defensive armor, not even spines. It is too large to live in a hole in a tree, and too weak to dig a burrow in the earth. It is too tired to walk on its feet, as the monkeys do, so throughout its queer life it hangs underneath the branches of the trees in which it finds its food." (Hornaday.)

The armadillos occur principally in South America, but one species, the nine-banded armadillo, *Tatu novemcinctum*, is found also in Mexico, Texas and Arizona. They are covered with hard bony plates which form a protecting case for all parts of the body. When attacked the animal draws in its legs and rolls up into a ball leaving exposed to its enemy only this bony shell.

The ant-eaters are also confined to South and Central America. The small mouth situated at the end of a long slender beak is entirely toothless. They devour great quantities of ants and thus help to reduce the numbers of these insects which are often great pests in tropical countries.

To the order *Sirenia* belong the manatees, or sea-cows, and the dugongs. These are aquatic, seal-like animals with the fore legs reduced to a pair of flippers and the hind legs wanting. One species of manatee, *Trichechus latirostris*, is still found off Florida, and others occur in the warm waters of the islands and along the coast of Mexico, Central and South America. The great Arctic sea-cow, *Hydrodamalis gigas*, once occurred abundantly in the Bering Sea region where it reached a length of twenty to thirty feet. The natives and the whalers used it for food until it was practically exterminated about 1780. The last animal of this species seen was killed in 1854.

The *Cete* are an order of aquatic mammals all more or less fish-like. The whales, dolphins and porpoises belong to this order. In all, the posterior limbs are so reduced that they

do not appear at all externally, while the forelimbs are developed as broad flattened paddles without distinct fingers or nails. The tail ends in a broad horizontal fin or paddle. The *Cete* are all predaceous, fish, pelagic crustaceans, and especially squids and cuttle-fishes forming their principal food. Most of the species are gregarious, the individuals swimming together in "schools." Some of them can remain under water for a long while but they must all come to the surface to breathe. As the whales come to the surface they blow the air from their lungs out through the blow holes on top of their head. This air is so heavily laden with moisture that it is usually supposed and said that the whale is actually "spouting" water.

The whales comprise two families, the sperm whales, *Physeteridæ*, with numerous teeth in their lower jaw, and the whalebone whales, *Balænidæ*, which have in the mouth, instead of teeth, many long parallel plates with fringed edges, the valuable "whalebone" of commerce. The great sperm whales reach a length of eighty feet of which the head forms nearly one-third. They feed on various kinds of fish and squid. They are hunted for the sperm oil, which is obtained from the blubber or layer of fat that lies under the skin, and for the spermaceti which is obtained from the head and is used in making candles and ointments. The teeth of these whales are also of considerable value, being used for ivory. Of the whalebone whales, the sulphur-bottom whale of the Pacific Ocean, reaching a length of nearly one hundred feet, is the largest, and hence the largest of all living animals. These great monsters feed on minute shrimp-like crustaceans and other small organisms swimming at or near the surface of the sea. The whale swims along with its mouth wide open, the mass of "whalebone" plates acting as a strainer until a mouthful of dainty food is procured. The sulphur-bottom whale, the right whale, the hump-back whale, the bow-head whale and others are all hunted for the "whalebone," or baleen, and for the oil. The bow-head or polar whale is the most important commercially, a single specimen sometimes yielding 3500 pounds of whalebone and 275 barrels of oil.

The family *Delphinidæ* includes the dolphins and porpoises

and certain others some of which yield valuable oil. It also includes the vicious killer "whale," or orca, which "has the appetite of a hog, the cruelty of a wolf, the courage of a bulldog, and the most terrible jaws afloat." Although they are not more than fifteen to twenty feet long three or four of them will attack and destroy even the largest whale.

The hoofed mammals, order *Ungulata*, include some of the most familiar mammal forms. Most of the domestic animals, as the horse, cow, hog, sheep and goat, belong to this order, as well as the familiar deer, antelope, and buffalo of our own land, and elephant, rhinoceros, hippopotamus, giraffe, camel, zebra, etc., familiar in zoological gardens and menageries. The order is a large one, its members being characterized by the presence of from one to four hoofs, which are the enlarged and thickened claws of the toes. The Ungulates are all herbivorous, and have their molar teeth fitted for grinding, the canines being absent or small. The order is divided into the *Perissodactyla*, or odd-toed forms, like the horse, zebra, tapir, and rhinoceros, the *Artiodactyla*, or even-toed forms, like the oxen, sheep, deer, camels, pigs and hippopotami, and the *Proboscidia*, the elephants. The Artiodactyls comprise two groups, the Ruminants and Non-ruminants. All the native *Ungulata* of our Northern States belong to the Ruminants, so-called because of their habit of chewing a cud. A ruminant first presses its food into a ball, swallows it into a particular one of the divisions of its four-chambered stomach, and later regurgitates it into the mouth, thoroughly masticates it, and swallows it again, but into another stomach-chamber. From this it passes through the other two chambers into the intestine.

The deer family, *Cervidæ*, comprises the familiar Virginia, or red, deer of the Eastern and Central States and the white-tailed, black-tailed, and mule deers of the West, all belonging to the genus *Odocoileus*, the great antlered elk or wapiti, *Cervus canadensis*, the great moose, *Alce americana*, largest of the deer family, and the American reindeer or caribou, *Rangifer caribou*. All species of the Cervidæ have solid horns, more or less branched, which are shed annually. Only the males (except with the reindeer) have horns. The antelope, *Antilo-*

capra americana, common on the Western plains, also sheds its horns, which, however, are not solid and do not break off at the base as in the deer, but are composed of an inner bony core and an outer horny sheath, the outer sheath only being shed. The family *Bovidæ* includes the once-abundant buffalo, or bison, *Bison bison*, the big-horn, or Rocky Mountain sheep, *Ovis canadensis*, and the strange pure white Rocky Mountain goat, *Oreamnos montanus*. The buffalo was once abundant on the

FIG. 132.—Buffalo, *Bison bison*, in Golden Gate Park, San Francisco, Cal.

Western plains, travelling in enormous herds. But so relentlessly has this fine animal been hunted for its skin and flesh that it is now practically exterminated. A small herd is still to be found in Yellowstone Park, another in Canada, and other protected groups live in parks and zoological gardens. On Jan. 1, 1913, a total of 3,453 bison were alive in North America. In all of the *Bovidæ* the horns are simple, hollow, and permanent, each enclosing a bony core.

Many of these native, wild hoofed animals have been impor-

tant as a source of food, but nearly all are now so reduced in numbers that they are little hunted except for sport. The domesticated mammals, the most important of which belong to this order, are discussed in Chapter XXVI.

The order *Glires*, the rodents, or gnawers, is the largest of the orders of mammals, and includes the rabbits, porcupines,

FIG. 133.—A buffalo, *Bison bison*, killed for its skin and tongue, on the plains of western Kansas, forty years ago. (Photograph by J. L. Knight.)

gophers, chipmunks, beavers, squirrels, rats and mice. The special arrangement and character of the teeth are characteristic of this order. There are no canines, a toothless space being left between the incisors and molars on each side. There are only two incisor teeth in each jaw (rarely four in the upper jaw). These teeth grow continuously and are kept sharp and of uniform length by the gnawing on hard substances and

the constant rubbing on each other. The food of rodents is chiefly vegetable.

The order is divided into several families of which the following are the most common: the *Leporidæ*, the rabbits and hares; the *Erethizontidæ*, the porcupines; the *Geomyidæ*, the

FIG. 134.—Chipmunk. (Permission of Camera Craft.)

pocket gophers; the *Zapodidæ*, the jumping mice; the *Dipodidæ*, the pocket mice and kangaroo rats; the *Muridæ*, the mice and rats; the *Castoridæ*, the beavers; and the *Sciuridæ*, the squirrels, woodchucks and prairie-dogs.

Of the hares and rabbits, the cottontail, *Lepus sylvaticus*, and

the common jack-rabbit, *L. texanus*, are the best known. The cottontail is found all over the United States, but shows some variation in the different regions. There are several species of jack-rabbits, all limited to the plains and mountain regions west of the Mississippi river. The food of rabbits is strictly vegetable, consisting of succulent roots, branches, or leaves.

As long as they confine their feeding to wild plants, or even to cultivated field crops, the damage that they do is usually not great, although when very abundant they may materially injure wheat or alfalfa fields. In the gardens, however, where they will attack all kinds of vegetables, they sometimes cause considerable annoyance, or even serious loss. Trees and shrubs are often injured, especially in the winter time when the ground is covered with snow and there is little other green food to be had. The rabbits eat the ends of the branches within their reach or gnaw the bark, sometimes girdling the tree. The most satisfactory remedy, where the rabbits are abundant enough to be a nuisance, is to allow hunters to kill them. Most rabbits are of fine flavor, especially when young. The cotton-tails are usually considered superior even to Belgian hares and other domesticated species. In some regions where the country is sufficiently open "rabbit drives" are organized, and as many as 10,000 to 20,000 rabbits are killed in a single drive. Various kinds of traps are used in the orchards and gardens, and poisoning is sometimes resorted to, but the latter is always dangerous. Rabbit-proof fences are effective and although expensive are often profitable. Trees may be protected with close meshed wire or by veneer, cornstalks, sacking or other substances. Most of the paints or smears usually recommended to be put on the trees are apt to injure them. The sulphur-lime mixture, such as is used for scale insects (see page 415) has proved a very effective repellent wash in many places.

Nearly fifty years ago the common rabbit of Europe was introduced into Australia as a game animal. In the absence of their natural enemies the rabbits multiplied so rapidly that they soon became serious pests and have cost the country millions of dollars, $3,500,000 being the estimated annual loss.

The skins are shipped in great quantities to Europe, where the fur is used in making many articles such as boas, muffs, hats and trimmings. The fur of the American rabbits is but little used except by the Indians.

There are two North American species of porcupines, an Eastern one, *Erethizon dorsatus*, and a Western one, *E. epixanthus*. The quills in both these species are short, being only an inch or two in length, and are barbed. In some foreign porcupines they are a foot long. They are loosely attached in the skin and may be readily pulled out, but they cannot be shot out by the porcupine, as is popularly told. The little guinea-pigs, *Cavia*, kept as pets, are South American animals related to the porcupines. Because of the ease with which they can be reared and handled, and for certain technical reasons, guinea-pigs are much used in physiological and bacteriological laboratories for experimental purposes. The sacrifice in this way of a few thousand guinea-pigs has aided in enormously increasing our knowledge of the causes of and remedies for infectious disease.

The pocket-gophers, of which there are several genera and species mostly inhabiting the central plains, are rodents found only in North America. They all live underground, making extensive galleries. They are very destructive to such crops as alfalfa, clover, grains, potatoes, and to many others, and often cause the loss of thousands of dollars in orchards by destroying the roots or girdling the trees and thus quickly killing them. Gophers may be poisoned or trapped. Small bits of carrots, potatoes, raisins, prunes or other substances may be poisoned by placing a small amount of strychnine in them; an amount equal to about half a grain of wheat is sufficient. The poisoned baits should be placed in the main tunnel, not in the short lateral tunnels that are used for bringing the dirt to the surface. If placed in the lateral tunnels they may be covered over or pushed to the surface where other animals or birds may find them. Many special forms of traps are used, almost all of them good if sufficient care is taken in setting them. When the ground is not too dry success may often attend the use of carbon bisulphide. Rags or waste may be saturated with this liquid and placed in the hole which is then closed tightly, or

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ESSENTIALS
OF
MODERN CHEMISTRY

CHAPTER I

MATTER AND ENERGY

1. Why We Should Study Chemistry.—For many reasons the study of chemistry is very important. It remained for chemistry, the youngest of the sciences, to teach us the nature of such common things as the rusting of iron, the corrosion of metals, the souring of milk, the decay of foods, the action of acids on metals, and ordinary burning or combustion. For example, Plato suggested that during combustion some material escapes from the burning body, and that the heat and flames indicate the vigor with which the material rushes out. Later Stahl devised the "phlogiston" theory, in which it was assumed that "phlogiston" is present in all combustible material. In an early chapter the real nature of combustion will be studied. The introduction of the balance in modern chemistry furnished us with an explanation which is not based upon assumption, but upon facts that may be readily demonstrated by experiment.

Chemistry is not only an excellent study from an intellectual standpoint, but its importance in the industrial

world can hardly be over-estimated. By nature man is a constructive being. Before he can manufacture complex substances, however, he often finds it necessary to break them up to study their components. This work of determining "what" a substance contains, or of finding out "how much" of each constituent is present, is the sphere of the *analytical* chemist. For example, indigo was at one time obtained entirely from the plant kingdom. It was analyzed and its composition studied. In 1880 chemists learned how to put together its constituents, and at present the bulk of the indigo in the market is a manufactured product. Oil of wintergreen is another substance that can be manufactured at a cost much below that of extracting the natural product.

It is part of the work of the chemist to discover methods of saving and utilizing by-products. Glycerin, a by-product obtained from the manufacture of soap, is at present more valuable than the soap itself. In the manufacture of illuminating gas, coke, coal-tar, and ammonia are all valuable by-products. At one time coal-tar was considered almost worse than useless. Now scores of products are made from coal-tar and their economic value amounts to millions of dollars annually.

It has been quite truthfully said, "The civilization of a country may be estimated by the amount of sulfuric acid it uses." This statement concerning a single chemical emphasizes the relation of chemistry to the most vital questions of the present day.

2. Matter.—Anything that occupies space or takes up room is called matter. We detect its presence by the aid of one or more of the senses, as sight, smell, touch, or taste. All students recognize matter in the solid or liquid state. Every one knows that liquids occupy space, but not every one knows that gases take up room. It is impossible to pour water into a bottle filled with air or some other gas,

unless there is an opening by which the gas may escape as the liquid enters. Thus gases are included under the head of matter.

3. States of Matter.—There are three states of matter: *solids, liquids, and gases.* Solids have a definite volume and a definite shape. They do not need lateral support to maintain their form. In fact most solids are so rigid that they may be subjected to considerable pressure without distortion. Liquids have a definite volume, but they take the shape of the containing vessel. Gases have neither a definite volume nor a definite shape. They expand and fill the containing vessel. Both liquids and gases are called *fluids,* from the Latin word *fluere,* meaning to flow.

4. Nature of Matter and the Kinetic Theory.—From its behavior, it is quite evident that all matter is made up of very small particles, called *molecules.* These particles are so small that they can not be seen even with the aid of the most powerful microscope. The best estimates show that a liter of gas at standard conditions of temperature and pressure contains 2.69×10^{23} molecules. It is estimated that if a drop of water were magnified until it became as large as the earth, its molecules, if magnified correspondingly, would be about as big as oranges. Despite this large number of molecules, the space between the molecules is much greater than that occupied by the molecules themselves. Small as the molecules are, they are believed to be made up of *atoms,* very small particles that are indivisible by either physical or chemical means.

Several facts show quite conclusively that the molecules of matter are in rapid motion with respect to one another. The fact that liquids evaporate is evidence of this motion. The decided odor of naphthalene, musk, and camphor, and the rapid diffusion of illuminating gas through a room when a gas-cock is opened, furnish added proof of molecular motion.

5. Measurement of Matter.—Two systems of measurement are in common use, the English system and the Metric system. The English system is probably well enough known so that it need not be discussed here.

The Metric system is a decimal system. The unit of length is the *meter*. It is divided into tenths, or *deci*-meters; into hundredths, or *centi*-meters; and into thousandths, or *milli*-meters. Ten meters make 1 *deka*-meter; 100 meters, 1 *hekto*-meter; and 1000 meters, 1 *kilo*-meter. Arranged in tabular form:

10 millimeters	(mm.)	make 1 centimeter	(cm.).
10 centimeters	(cm.)	make 1 decimeter	(dm.).
10 decimeters	(dm.)	make 1 meter	(m.).
10 meters	(m.)	make 1 dekameter	(Dm.).
10 dekameters	(Dm.)	make 1 hektometer	(Hm.).
10 hektometers	(Hm.)	make 1 kilometer	(Km.).

The meter equals 39.37 inches; 1 inch equals 2.54 centimeters (Fig. 1).

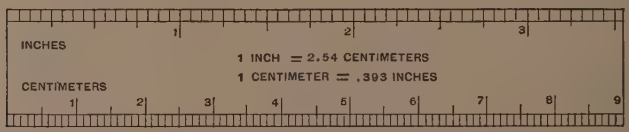

FIG. 1.—Comparison of Metric and English units of length.

The metric unit of capacity is the *liter*. The same prefixes are used as in the table of length. A cubical box 10 centimeters on a side holds 1 liter; thus it is equivalent to 1000 cubic centimeters. It is slightly smaller than the *dry* quart and a little larger than the *liquid* quart (Fig. 2).

The metric unit of weight is the *gram*. The same prefixes are used as in the table of length. *One liter of distilled water at 4°C., weighs 1 kilogram.* Therefore 1 cubic

centimeter of water weighs 1 gram. The kilogram weight equals about 2.2 pounds; 1 ounce equals a little more than 28 grams (Fig. 3).

6. Energy.—*Energy is the capacity for doing work.* It requires some form of energy to produce motion in matter.

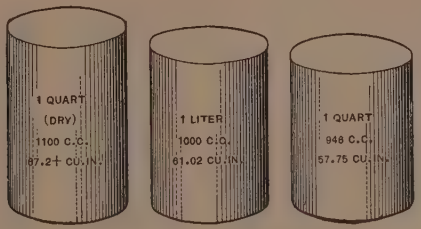

FIG. 2.—Comparison of Metric and English units of capacity.

In fact to bring about any change in the condition of matter energy is needed. In turn, changes in matter itself may liberate various forms of energy.

7. Kinds of Energy.—There are several kinds of energy: *mechanical energy; heat energy; electrical energy; light energy; and chemical energy.* For doing chemical work all of the above-named are used extensively. *Energy can not be destroyed.* It is possible to *convert* or *transform* one kind of energy into a different form. Thus it is possible to use heat energy from burning coal to produce steam; the steam may be used in a steam-engine to furnish mechanical energy; electrical energy may be generated by a dynamo turned by such mechanical energy; and electrical energy may in turn be easily transformed into heat, light, or mechanical energy.

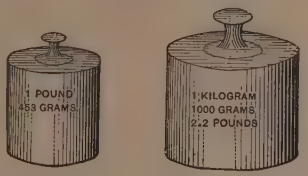

FIG. 3.—Comparison of Metric and English units of weight.

SUMMARY

Chemistry is a cultural study since it answers many important questions. It is intensely practical, since it is so important a factor in manufacturing and industrial operations.

Matter is anything that occupies space.

There are three states of matter: solids, liquids, and gases.

According to the kinetic theory, matter is made up of molecules; these molecules are in very rapid motion.

The Metric system is used extensively in scientific work. The meter is the unit of length; the liter, the unit of capacity; and the gram, the unit of weight. In the laboratory solids are usually measured by weight; gases by volume; and liquids by either volume or weight.

Energy is the capacity for doing work. There are several kinds of energy: mechanical, heat, light, electrical, and chemical energy.

PROBLEMS

1. Find the number of grams in a pound. Find your weight in kilograms.

2. Reduce your height to meters. Find the value of 10 Km. in miles.

3. What must be the dimensions in decimeters of a cubical box whose capacity is 1 liter? How many cubic centimeters are there in 22.4 liters?

4. What advantages has the Metric system over the English system?

5. A pneumatic trough is 30 cm. long, 2 dm. wide, and 80 mm. deep. What is its capacity in cubic centimeters? In liters?

6. A bottle holds 1650 c.c. How many grams of water does it hold? How many liters? How many kilograms?

7. A test-tube 6 in. long has an internal diameter of $\frac{3}{4}$ in. How many cubic centimeters does it hold?

Topic for Reference.—History of the Metric System. See Appendix C.

CHAPTER II

ELEMENTS—MIXTURES—COMPOUNDS

8. Classes of Substances.—Substances may be classified as *elements, mixtures, and compounds.* The number of elements known is not very great, but the number of mixtures and compounds is enormous. When the various elements are studied in chemistry, the more important compounds formed by them are usually discussed at the same time as a matter of convenience and for purposes of classification.

9. The Element is the Limit of Analysis.—In the preceding paragraph we learned that the number of complex substances is very great. The analysis of a complex substance, or of a chemical compound, consists in separating it into simpler substances. We soon reach a point, however, where the constituents do not yield to further sub-division. For example, if we heat the red powder known as mercuric oxid, it decomposes readily, yielding two substances, mercury and oxygen. All attempts to decompose either mercury or oxygen into still simpler substances have resulted in failure. For that reason they are called *elementary substances,* or *elements.*

It is quite impossible to prove that any given substance is an element. We know that no one has yet succeeded in decomposing oxygen into simpler substances, but we can not prove that some one will not succeed in doing so in the future by the use of some as yet untried method. At one time water was considered an element, but it has since been decomposed into hydrogen and oxygen, two simpler substances.

10. Number and Distribution of the Elements.—At the present time slightly more than eighty substances are known that chemists have good reason to believe are elements. New ones are being discovered from time to time. Such substances as iron, copper, oxygen, nitrogen, lead, silver, and gold have been tested in almost every conceivable manner without their decomposition into other substances. Of the eighty-odd elements known, not more than half are well known. Even the names of many elements are not familiar, even to well-educated persons. The student will be interested in comparing the list of fairly common elements given on page 9 with the complete list given on the back cover.

According to an estimate made by Clarke, about 98 per cent. of the earth's crust is composed of eight elements in about the following proportion:

	Per cent.
Oxygen	47.0
Silicon	28.0
Aluminum	7.9
Iron	4.4
Calcium	3.4
Magnesium	2.4
Sodium	2.4
Potassium	2.4

11. Names and Symbols.—Metals recently discovered have the Latinized ending "um" or "ium," as sodium, calcium, potassium, radium, and aluminum. The stem used may depend upon some characteristic property of the element, the source from which it is obtained, or it may be the name of the country in which the element was discovered.

For convenience, symbols are used to designate elements. They serve as abbreviations, but the student will learn

later that a symbol means more than an abbreviation. For example, the letter O is used to represent oxygen; it also means one atom of oxygen, or the smallest particle of oxygen that can enter into combination with other elements. Usually the first letter of the name of an element is used as its symbol, as H for hydrogen, N for nitrogen, or C for carbon. When the names of several elements begin with the same letter, some other letter is used with the initial letter, as Cl for chlorin, Ca for calcium, and Cr for chromium. In several cases the symbol is derived from the Latin name for the element. Thus Fe from the Latin word *ferrum* is the symbol for iron; Pb from the Latin word *plumbum* is the symbol for lead; and Na from *natrium* is the symbol for sodium. The following table gives the names and symbols of the most common elements.

(The following table is for reference only.)

Aluminum	Al	Lead	Pb
Antimony	Sb	Lithium	Li
Argon	A	Magnesium	Mg
Arsenic	As	Manganese	Mn
Barium	Ba	Mercury	Hg
Bismuth	Bi	Nickel	Ni
Boron	B	Nitrogen	N
Bromin	Br	Oxygen	O
Cadmium	Cd	Phosphorus	P
Calcium	Ca	Platinum	Pt
Carbon	C	Potassium	K
Chlorin	Cl	Radium	Ra
Chromium	Cr	Silicon	Si
Cobalt	Co	Silver	Ag
Copper	Cu	Sodium	Na
Fluorin	F	Strontium	Sr
Gold	Au	Sulfur	S
Hydrogen	H	Tin	Sn
Iodin	I	Tungsten	W
Iron	Fe	Zinc	Zn

12. Metals and Non-metals.—Elements are divided into two classes, metals and non-metals. Substances that have a luster like steel, that conduct heat and electricity fairly well, are called metals; substances like sulfur and phosphorus, that have a glassy or waxy luster, and are poor conductors of heat and electricity, are classed as non-metals. This classification is an old one that is still retained, although it is not strictly correct. The division line is not sharply defined, since such elements as arsenic and antimony, being on the border line, have some metallic and some non-metallic properties. Such elements are sometimes called metalloids.

13. Mixtures and Compounds.—When a substance is made up of two or more elements, they may be mechanically mixed, or they may be chemically combined. The following experiment serves to show the differences between a mixture and a compound. If we put a few iron filings on a piece of paper and add to them a little powdered sulfur, there is no apparent action between them. No heat is gained or lost, no light is emitted, and there is no evidence that electricity is produced. The two elements may be *mixed* in any proportion. If we pass a magnet over the mixture the iron filings are attracted to it and may be readily separated from the sulfur. If we put the mixture in a test-tube and heat it slightly, a vigorous action takes place. The contents of the tube begin to glow, and even if the external heat is withdrawn, the whole mass soon becomes red hot. Subsequent examination of the product formed shows that an entirely new substance with different properties than either the iron or the sulfur possessed has been formed. It can not be decomposed by mechanical means. If the ingredients had been weighed, the results would have shown that 7 parts by weight of iron always combine with 4 parts by weight of sulfur. Any excess of either element is always left uncombined.

Air, flour, baking powder, and the various kinds of soils are examples of mixtures. The per cent. of their constituents may vary widely. Water, starch, sugar, and salt are examples of compounds. Their constituents are always present in the same proportion by weight. The several differences between a mixture and a compound may be summarized in the following contrasting table:

Mixture	Compound
In a mixture the constituents may be present in any proportion.	*A compoumd always has a definite composition by weight.*
In preparing a mixture, there is no evidence of any chemical action, such as the evolution of heat, light, gas, or electricity.	*In the preparation of a compound, some evidence of chemical action is apparent. Heat or light may be emitted or absorbed, an electric current produced, or a gas liberated.*
A mixture may often be separated by mechanical means.	*The constituents of a compound can be isolated by chemical means only.*

14. Law of Definite Proportions.—John Dalton was the first to call attention to the chief difference between a mixture and a compound. This difference is clearly formulated in Dalton's law of definite composition or proportion: *Every compound has a definite composition by weight.* This is the fundamental law upon which the whole science of modern chemistry is based.

15. Formulas.—A formula is often used to show of what constituents a compound is made up. The formula for water is H_2O. This formula represents 1 molecule of water. It shows that each molecule of water contains 2 atoms of hydrogen and 1 atom of oxygen. If we write $2H_2O$, the expression represents 2 molecules of water, each containing 2 hydrogen atoms and 1 oxygen atom. The number before a formula always shows the number of

molecules taken; the number following each symbol shows the number of atoms of that element in each molecule of that compound.

16. Properties of Elements and Compounds.—We identify elements and compounds by means of their properties. There are certain *general* properties common to all matter. Of course such properties are of no value for identification purposes. However, all substances have certain *special* properties by means of which we recognize them. The more peculiar the properties of a substance, the easier it is to identify it. Alcohol is easily recognized by its peculiar odor. Ammonia may be detected by its odor. Table salt may be identified by its taste. Since the number of compounds that may be formed from the elements is almost infinite, the only method suitable for the chemist is to classify compounds according to *similar* properties, and then identify each one by its *peculiar* individual properties.

In studying properties we distinguish between physical properties and chemical properties. Under physical properties are included *color*, *odor*, *taste*, *solubility in water*, *hardness*, *density*, *conductivity of heat and electricity*, *tenacity*, *ductility*, and *malleability*. Under chemical properties we include all chemical activity such as the interaction of the substance with *water*, *air*, *acids*, and *alkalis*.

SUMMARY

Substances are classed as elements, mixtures, and compounds. An element is a substance that no one has succeeded in decomposing into simpler substances. More than eighty elements are known. About half of these are common. It is estimated that more than 98 per cent. of the earth's crust is made up of only eight elements. Elements are classed as metals and non-metals.

Symbols are used to represent elements. The symbol is usually the first letter of the name of the element or the first letter and some other letter whose sound is conspicuous as the name of the element is pronounced.

A substance made up of two or more elements is either a mixture or a compound. If the elements are chemically combined and their proportion definite, the substance is a compound. In a mixture the constituents may be in any proportion.

A formula is a group of symbols used to show the composition of a compound. It also shows the number of atoms in each molecule of that compound.

Elements and compounds are identified by means of certain special properties. Such properties are either physical or chemical.

QUESTIONS

1. Name five elements; four compounds; three mixtures.

2. If you were given a mixture of sand and sugar, how could you separate them?

3. How could you separate the iron from a mixture of iron filings and sulfur?

4. State some of the characteristic properties of (*a*) gasoline, (*b*) alcohol, (*c*) gold, (*d*) copper, (*e*) silver.

5. How would you distinguish between alcohol and gasoline? How would you tell gold from copper? Salt from sugar?

CHAPTER III

CHANGES IN MATTER

17. Physical and Chemical Changes.—Changes in matter are of two kinds, physical and chemical. In a physical change the matter does not lose its characteristic properties. Its form or its state may be changed. The melting of ice, changing water to steam, breaking glass or wood, and dissolving salt in water are all examples of physical change. In none of these cases does the substance lose its identity; the molecule is not broken up.

In a chemical change, the substance loses its identity and forms a new substance or substances with new properties. Molecules are made up of small parts called atoms. During a chemical change, the molecule may be decomposed, its atoms may be re-arranged, or a more complex molecule may be built up by putting together certain elements. The burning of wood, the action of an acid on metals, the decay of plants, and the cooking of meat and eggs are all examples of chemical change.

18. Causes of Chemical Change.—*Heat*, *light*, *electricity*, and *solution* are the most common causes of chemical change.

Wood does not begin to burn until it is heated strongly; the head of a match is ignited by the heat produced by friction; heat causes the chemical change in the baking of bread and the cooking of foods. In the laboratory heat is generally applied to bring about a chemical change. Heat is also used to increase the speed of a chemical reaction. It has been determined that the speed at which

wild species of dog-like animal, but in several. These wild ancestors of the dog are certain wolves and jackals of various lands. Dogs are probably descended from at least seven such wild species, namely, the jackal, *Canis aureus*, of western Asia, the landga, *Canis pallipes*, of India, the jackal wolf, *Canis anthus*, of northeast Africa, the walgie, *Canis niger*, of Thibet, and the coyote, *Canis latrans*, and dun-gray wolf, *Canis occidentalis*, of North America.

The house cats, on the contrary, as various and as widely distributed as they are, seem to be all descended from a single wild species. This is the dun wild-cat, *Felis maniculata*, of northeast Africa. All of the present races of house cats trace their lineage back to Egypt. That the Egyptians were much given to the possession and care of cats the numerous cat mummies of their graves show. Cats were a sacred animal for them under the special protection of the goddess Bast, a goddess introduced into Egypt by Semitic influence. The fanciers now recognize about thirty established races of cats. They are grouped in two main classes, namely, long-haired cats and short-haired cats, and in both groups appear certain repeated colors as white, cream, gray, silver, yellow, black, smoke "blue," brown, orange, "red," etc. The pattern may be solid color or banded (tabby) or spotted (tortoise-shell) in different colors. There is a Mexican hairless cat (just as there is a Mexican hairless dog). The so-called Manx cats are always tailless, but very short-tailed or even tailless individuals occur occasionally in several other races, at least among the short-haired kinds.

The horses of modern times can be traced back to two wild ancestors, namely, *Equus przewalski*, of northern Asia, from which all the Oriental, Mongolian, Arabian, North African and East European races have sprung; and *Equus caballus fossilis*, or the diluvial horse, of Europe, from which the German, Norman, English and West European horses generally have risen. In America fossil horses have been found back through a series of geologic ages as far as the beginning of the Tertiary Age forming a connected series from the small *Eohippus* of the lower Eocene period, about the size of a fox,

and with four toes and splint of the fifth digit on each hind foot; through *Protorohippus* and *Orohippus* of the Middle Eocene, about fourteen inches high, with four toes on front feet and three toes on hind feet, and no splints; through *Mesohippus* of the Oligocene, about the size of a coyote, and with three toes on all its feet; through *Protohippus* and certain other kinds of the Middle Miocene, about as large as Shetland ponies and with three toes on all feet but with the side toes not touching the ground; to *Equus*, which first appeared in the Pleisto-

FIG. 139. Restoration of the four-toed horse; based on a mounted skeleton, sixteen inches high, in the American Museum of Natural History. (After C. R. Knight.)

cene with only one developed toe and splints of the second and fourth on each foot.

The color of the prehistoric horse is not known, but it was probably dun with more or less well-defined stripes like a zebra. The bones of human beings have been found associated with those of prehistoric horses in South America and in Europe. Remains of horses are associated in Europe with human relics of the Bronze Age, and figures of the wild horse

are abundant among the drawings made by late Glacial man on cave walls in Spain and France.

About a dozen living natural species and sub-species of the genus *Equus* are known, including horses, asses, zebras, and the now nearly if not quite extinct quagga. Of domesticated races of horses and asses the number must run to more than a score of well-marked distinct breeds, varying in size from the

FIG. 140.—Arion, a record-holding American trotting horse. (After Plumb.)

minute ponies of the north British islands to the great Clydesdale and Percheron draught animals.

Donkeys have been derived from two wild species, the Nubian Desert donkey, *Equus tæniopus*, and the onager, *Equus onager*, of eastern Asia. Tame donkeys are figured in the earliest of Egyptian and Assyrian drawings and carvings.

The races of domesticated hogs are also descended from two wild races, the European wild boar, *Sus scrofa*, and another

FIG. 141.—The Banteng, *Bos sondaicus*, or wild ox of Java and South Asia. (After Keller.)

FIG. 142.—White Hall Sultan, a Shorthorn prize bull. (After Plumb.)

species, *Sus vittatus*, from eastern Asia. From this latter the swine of China and those of the Romans and indeed most of the European races have descended. The lake dwellers of Switzerland had domesticated hogs, and pig remains have been found with prehistoric relics in Denmark. China has had domesticated swine for thousands of years.

The many races of cattle all seem to trace back to two sources, the wild banteng, *Bos sondaicus*, of Java and South

FIG. 143.—The wild sheep of the Trans-Caspian steppes, *Ovis arkal*. (After Keller.)

Asia, from which are derived the zebus, the old Egyptian longhorns, and many of the races of Europe, such as the Spanish, Albanian, Sardinian, Polish and brown Alpine cattle; and the primitive wild ox of Europe, *Bos primigenius*, from which have descended most of the English, North German, and Holland races. This wild species persisted in Germany until the twelfth century and in Poland up to the eighteenth century. A few persons in America have tried to create a hybrid race by

crossing domestic cattle with the buffalo, but probably no permanent result has been reached.

The domesticated races of sheep seem to have had three original wild sources, *Ovis musimon* of South Europe, *Ovis arkal* of Western Asia, and *Ovis tragelaphus* of North Africa. Most of our present European and American races come from the second named of these wild kinds. The earliest certain remains of tame sheep appear in the Stone Age. In the Bronze

FIG. 144.—Typical American Merino ewe, a highly specialized breed of sheep, with fine, close-set wool. (After Shaw.)

Age sheep domestication was well developed. The oldest Assyrian drawings picture domesticated sheep, among which the still persisting fat-tailed race appears. The Egyptians had domesticated sheep in the times before the Pharaohs.

Our goats also are descended from three wild races, namely, *Capra ægagrus* of Western Asia, *Capra falconeri* and *Capra jemlaica* of the Himalayas. The earliest prehistoric indications of tame goats come from the times of the Lake-dwellers. In the Bronze Age they were common.

Other mammals that are represented by domestic races are the camel, the elephant, the water buffalo, the rabbit, the ferret, the reindeer, the lama and alpaca, the guinea-pig, the mouse, the rat, etc. But, excepting the rabbit, the domesticated forms of these animals are only wild species tamed and reared under man's hand but not much modified by breeding. There are about fifteen races of domesticated rabbits all of which probably trace their lineage back to wild species native to Spain and Southern France.

FIG. 145.—Silver-laced Wyandotte cockerel.

Of birds there are domesticated races of doves, chickens, turkeys, ducks, geese, swans, pea-fowls, pheasants, canary birds, ostriches, cormorants and others. Of these the doves and chickens are represented by the most varieties. Brown, an English authority on domestic birds, lists more than seventy races of chickens now living, thirteen races of ducks, ten of geese, and eight of turkeys. Of pigeons there must be nearly as many domestic races as there are of chickens. And yet all of

them, with all their extraordinary variety of crests, and ruffs, and tails and plumage pattern, and all their various special manners such as tumbling, dancing, and the like, are descended from a single wild species, the common rock dove, *Columba livia*, of Europe, Asia and North Africa.

The domestic races of chickens are by some naturalists also held to be descended from a single wild species, the jungle fowl, *Gallus bankiva*, which ranges from Hindukoosh to the Chinese island of Hainau and through most of the Indonesian islands. But other naturalists believe that one or two other wild species of fowl are concerned in the ancestry of our barnyard hen.

FIG. 146.—Wild jungle fowls, *Gallus bankiva*, of India. (After Brown.)

The domestic ducks are derived from the wild duck, *Anas boschas*, and have evidently originated from this ancestor independently both in China and in Europe. The domestic geese seem to have an older origin than the ducks; in fact, geese are probably the oldest of domesticated birds. The ancestor of our races is the wild species, *Anas cinereus*. The Chinese races, however, are descended from *Anas cygmoides*, and the early Egyptians seem to have tamed and used the Nile goose, *Chenalopex egyptiaca*.

The domesticated peacocks are descended from a wild species

of India, *Pavo cristatus*. The turkeys trace their ancestry to the wild *Meleagris gallopavo* of North America. The swans are really only tamed wild kinds. Common species are the white swan of Europe, *Cygnus olor*, the black swan of New Holland, *Cygnus atratus*, and the black-necked swan of South America, *Cygnus nigricollis*. The pheasants also are so far practically only partially tamed wild species, whose eggs are usually hatched under turkeys. Most of the kinds kept are from the Orient.

Canary birds are descended from the wild species, *Fringilla canariensis*, of the Canary Islands. But there has been some crossing of them with other species of wild birds, especially certain sparrow and finch kinds. There are now numerous domesticated races which vary structurally and in color-pattern as well as in voice. Many of the characters resemble the ruffs, crests, and other plumage eccentricities of pigeons. The principal place of canary bird breeding at present is in the Harz Mountains of Germany.

Tamed cormorants are used by the Chinese and Japanese as fishing birds, somewhat as falcons were used in days of old as hunting birds. Indeed, in these same days cormorants were used for sport. Charles I of England had a "master of the cormorants." Nowadays, however, cormorant fishing is a practical means of gaining food. A ring is placed about the neck of each bird so as to prevent it from swallowing the fish it catches. Several different species of cormorants are thus used.

The ostrich is the most recent addition to the ranks of domesticated birds. The tamed species is derived directly from the widely distributed African ostrich, *Struthio camelus*.

Besides mammals and birds two or three species of fish, such as the carp and goldfish, may be called domesticated. This is certainly true of the goldfish, which is a product of Chinese animal breeding. Some most bizarre forms have been produced in the thousand or more years in which this fish has been a subject of selection and hybridization.

There are also, finally, at least two species of insects that have a right to be called domesticated animals, namely, the honey-

bee and the mulberry silk-worm. The honey-bee, *Apis mellifica*, has been long used by man to obtain honey from, but only in modern times has the species been the subject of true "breeding." However, already several distinct races have been produced. The bee is native to Europe and Asia, and "wild" honey-bees in America are only communities established by wandering swarms from hives, or from other "wild" communities which have descended from such escaped swarms (see p. 185).

The silk-worm, *Bombyx mori*, has on the contrary been an artificially bred animal for five thousand years, and scores of races, with differently colored and shaped cocoons, exist. The actual wild species from which the domesticated races are descended is not known, but it is most likely some one of the several wild species of northern India. The cocoons of certain of these wild Indian species are to-day still collected for the silk and sold under the commercial name of "Tussoor" silk. The ancient breeding and care of silk-worms was mostly done in China and Japan. To-day it is carried on even more extensively in France and Italy (see p. 176).

CHAPTER XXVII

ANIMAL LIFE AND EVOLUTION

In all this book so far, we have made but little reference to that phase of the study of animals which is usually called animal evolution, or animal bionomics. We have taken the many species of animals, and the great variety of form and manner of life of these species, as facts, not problems; and we have even described many kinds of extraordinary adaptations, or modifications of structure and life to fit their possessors to special or unusual conditions, without suggesting that the question of the origin of these adaptations presents perhaps the most important and attractive problem in all the study of animals. We have postponed all such references deliberately in order, primarily, to accent the facts and problems of economic zoology throughout the book, and, secondarily, so that we might take up the evolutionary phase of animal life in a single compact chapter which should present an outline of the present-day status of knowledge and speculation on the subject. By putting this chapter of the book last in the present part we hope to leave as a final impression in the elementary zoologist's mind a special stimulus to further interest in and study of animal life. For it is exactly the evolutionary phase of animal study, the pursuit, that is, of the solution of questions as to the why and how and the origin and change in animal form and function and in animal kinds, which is the chief inspiration for the really philosophic study of animal life. The usefulness of knowing animals and their life, the enjoyment from a trained observation of their manifold forms and behavior, and the drill obtained from a careful study of their anatomy and physiology, are all really achieved by human endeavor of a different type from that required for the solution of evolutionary problems. And all of them are much more really within the possible grasp

of beginning students. So that we believe it well to postpone, as we have done in this book, any special consideration of the subjects associated with animal evolution until the student has had some personally acquired experience in the study of the other phases of zoology.

Evolution a Fact.—Although there is much discussion of the causes of evolution there is practically none any longer of evolution itself. Organic evolution is a fact, demonstrated and accepted. The many important open questions about evolution concern the factors that originate and guide it. Evolution means the blood relationship of organisms, their descent from common ancestors, the origin of kinds by the transformation or modification of other already existing kinds.

Evolution was not discovered by Charles Darwin nor by Lamarck, whose names are, however, the greatest of all those associated with it. It grew as a conception and a belief slowly through all the years from the times of the Greeks until it received its two most positive announcements and its two most plausible explanations from Lamarck and Darwin. Darwin, especially, presented such a full and convincing statement of the facts that prove the reality of evolution that he put evolution for all future time into our accepted understanding of nature. Hence to Darwin belongs the greatest merit that attaches to any name connected with the history of evolution.

The Causes, or Factors, of Evolution.—Evolution has two conspicuous conditions of animal (and plant) life to explain; first, all the different kinds of animals, and, second, all the various adaptations or special fittings of these kinds to their environment, so that they may live successfully as individuals and persist as species. The factors or causal agencies proposed to explain evolution must, therefore, to be acceptable, explain not only the origin of species but their adaptations. The factors proposed are many. Most conspicuous among them are those called variation, heredity, selection and segregation.

Variation and Mutation.—No two animals in the world are alike. Whether widely related or so-called "identical twins," products of a single egg, there are differences or variations be-

tween them. Among the thousands of worker bees in the same hive, all produced from eggs of the same queen, all reared under the same conditions, and all looking superficially very much alike, the trained eye of the student of variations has no difficulty in discovering differences in size, color, character of wing venation, number of wing hooks, etc., etc., differences indeed in the condition of any part or attribute carefully studied. The variations among the children in one family, among the puppies or kittens in one litter, or among human individuals or dogs or cats in general, are readily apparent, because we are familiar with the human and dog and cat bodies and attributes and readily recognize differences among them. But these differences are no less real and discoverable among the individuals of any other animal species.

These variations have been determined to be of two kinds. One kind, called acquired, or fluctuating, is produced chiefly by the inevitable environmental differences, kind and amount of food, etc., to which the different individuals of a species or even of one brood of the species, are subjected during their development from embryo to adult. These fluctuating variations are apparently not directly inherited, and hence probably have little to do with determining evolutionary change. They may have some importance in aiding or hindering the individual possessing them in their "struggle for existence," and by helping to save or lose the lives of these individuals determine who among them shall live to produce offspring and who shall not. But even those saved by the possession of a favorable fluctuating variation will not necessarily hand it on to their offspring, and thus impress it on a future race.

Variations of the second kind are called congenital, by which is meant that they depend primarily upon the character of the germ cells from which the new individuals are produced, and tend to appear whatever may be the character of the environment during development. These variations are directly heritable, that is, they are handed on to the offspring of the individuals possessing them. What causes them in the first place, what determines that the fertilized egg cells produced by different individuals of the same species shall differ among

themselves, is not at all understood as yet. These congenital, heritable variations may be, and usually are, small, but they may also be large, and are then called "sports." They have become especially familiar in recent years, under the name of "mutations," in the condition of combinations or groups occurring together, and thus making the individuals possessing them readily distinguishable from the parent type. Recent important discoveries in heredity have added to the interest and importance of these congenital variations, and have thrown a first faint light upon some of the conditions that attend their origin. It is undoubtedly true that they are really the most important actual beginnings of divergence among animals. They are the building stones from which new species and better adaptations are made. The importance of a knowledge of variations on the part of animal and plant breeders is obvious. It is especially important to distinguish between the heritable, or congenital, and the non-heritable, or acquired, variations. Only the first kind can be taken advantage of in the work of making new races.

Heredity.—The extent and manner in which we inherit our traits, both physical and mental, from our parents and ancestors has always been the subject of much speculation and study. One of the greatest among students of heredity was Francis Galton, only recently dead, whose studies, based largely on human pedigrees, resulted in the formulation about half a century ago of what is known as Galton's "law of ancestral inheritance." This states that on the average we receive one-half our inheritance from our parents, one-fourth from our grandparents, one-eighth from our great grandparents, one-sixteenth from our great, great grandparents, and so on backward by halving fractions, the sum of them all being one, or the total of our inherited qualities.

Such a law, or generalization, about heredity is of interest and value, but it gives us little basis on which to predict the specific character of the results of any mating. It applies to beings and characteristics in masses, and to average individuals. And it does not say what half, or fourth, or eighth, we shall get from any particular pair of ancestors. That is,

it does not say what characteristics, but only what proportion of a whole personality, shall be inherited. Hence it is a generalization that has not been of much practical use to breeders. Recently, however, great progress has been made in the study and elucidation of the exact heredity behavior, in successive generations, of specific traits in animals and plants, so that there are now well established certain new generalizations, or "laws," of heredity that are of immediate practical use to the breeder.

These new generalizations are known as the Mendelian principles of heredity because some of them were first discovered, by experimental work with plants, by Gregor Mendel, an Augustinian monk of Austria. He did his work and published his results in the years near 1860, but his conclusions remained practically unknown until 1900. The Mendelian principles cannot be expressed by any such single, simple and comprehensive generalization as the Galtonian law of ancestral inheritance. They do not attempt to treat of the inherited personality of the individual as a whole but concern themselves with the various separate characteristics or traits of the individual. In heredity that follows the Mendelian order—and it may be that all inheritance may be shown to do this—there is no real or permanent blending, of contrasted qualities, such as shortness and tallness, black and white, rough and smooth, etc. Each of these conditions is considered as an unmodifiable persistent unit character which can be combined with or separated from others but cannot be really blended with any. When two of these contrasted characters are brought together by a cross-mating the offspring of this mating may all show but one of these characters or may all show an apparent blending of them. But in the next generation, obtained by mating these offspring together, or with other similarly produced offspring, both of the original contrasted characters will reappear and by proper selecting and mating each may be made to breed pure again. If the original cross-mating has been of such a kind as to bring together several different pairs of contrasting characters, there will be opportunity in the second and later generations to pick out individuals showing new combinations of unit char-

acters and thus representing new types or races. This Mendelian feature of the combining and segregating, recombining and resegregating of unchangeable unit characters, has much importance for the practical breeder. It is a condition depending upon the character of the germ cells produced by the mated individuals and of their mated offspring rather than of the somatic or general bodily character. For although after the first cross-mating all of the offspring may be like only one of the parents as regards a certain character, it will be found that by allowing them to produce offspring of their own that their germ cells really represent, in presumably equal numbers, the contrasted characters of both parents.

The Mendelian order of heredity, although simple and easily understandable in its more apparent aspects, cannot be described in a few words. For a detailed account of it the student should read some such modern treatment of it as Punnett's "Mendelism," or Bateson's "Mendel's Principles of Heredity."

A special phase of the problem of heredity is that of the inheritance of acquired characters. The congenital characters of an individual, which are the outcome of the constitution of the germ cells that produced it, are undeniably heritable. Besides these characters, however, every individual acquires during its life certain characteristics and variations which are plainly due to the direct modification of the body parts and functions by its lesser or greater use of those parts, or by the direct influence of the abundance or scarcity of food, the rigor or mildness of climate, the amount of sunlight or moisture, etc. If these acquirements on the part of the parents are heritable, and many of them are plainly personal adaptations to the particular environment and circumstances of life in which the individual finds himself, then inheritance by the offspring would be a distinct advantage in leading a similar life. If they could start endowed at birth with all their parents had gained, their own going on with the adapting and modifying process would lead to still further change away from the original type, and thus in comparatively few generations a new type much better adapted to a particular kind of environment would be produced. This conception of personal

acquirement and adaptation, and the handing on of it by inheritance, resulting in a rapid cumulation of difference, was the basis of Lamarck's explanation of evolution.

But owing primarily to the keenly critical examination of the actual conditions and results of heredity by August Weissmann, present-day biologists believe that such acquired characters cannot be inherited, and hence that the modification and adaptation of species has all to depend for its beginning on favorable chance congenital variations, to be preserved and slowly cumulated by the action of natural selection. This belief makes it hard to gain a satisfactory conception of the actual methods of evolution, because it makes an enormous demand on variation, the precise working of selection, and the extent of geological time. So that there is a strong tendency among present-day biologists to search for other factors of species modification, and to try to determine by experiment the actual outcome in heredity of the modification of the body, and, if possible, of its germ cells, by external influences. As yet none of these experiments has given any sound basis for a reinstatement of the belief in the inheritance of acquired characters, but some of them do prove that the germ cells of animals can be directly influenced by external conditions, and that young, differing markedly from their parents, are produced by these influenced germ cells. That is, environmental influences which may modify the body may also modify the germ cells and thus cause change from the species type in the offspring which can be handed on by inheritance to their own progeny, but these changes will not be replicas of the acquired variations of the parents. Thus the only result on heredity of a better exercise of an animal's capacities will be to give its offspring more vigor and a better start in life perhaps, but it cannot endow the offspring with the parents' actual gain in fitness. Education can be handed on only by tradition, not by true germinal inheritance.

Another special subject in connection with heredity which should be mentioned in this book because of its importance in the work of the breeder, is that of the alleged advantage or disadvantage of in-breeding. In the light of the Mendelian

discoveries in-breeding is seen in a new aspect. The mating together of closely related individuals derives both its advantages and disadvantages from the probable occurrence in both parents of similar unit characters. Their offspring will thus get a double portion of each common character. If it is a good trait advantage will come of the mating, if a bad trait disadvantage. Thus to accent and fix quickly a good trait close breeding will be useful; to remove a bad trait out-breeding will be necessary. In addition out-breeding practically always adds vigor to the offspring. But in many cases of in-breeding vigor is not lost until after several or many in-bred generations have been produced.

Selection, Natural and Artificial.—Natural selection, which is a phrase summing up the presumable result of the interaction on animals and plants of several distinct natural causes and conditions, has been generally considered since Darwin's time to be the principal factor in evolution. It is the factor chiefly relied on by Darwin in his explanation of evolution, and its formulation is Darwin's principal original contribution to evolutionary discussion.

Natural selection depends upon, first, the geometrical ratio of reproduction, resulting in the production of more individuals than there is food or space for, this overproduction of living creatures necessitating a "struggle for existence" among them; second, the universal occurrence of variations, small or large, among all the myriads born; third, the presumption that some of these variations will give advantages to certain individuals in this struggle, resulting in their success and growth to maturity and production of young; fourth, the inheritance by the young of the advantageous variations of their parents, and their handing on of them to their own succeeding generations thus constituting a new race or species characterized by the original new variations and succeeding new and better ones. Thus there is a "natural selection" of individuals within a species, and also a "natural selection" of specially favored species in their competition with other species. The whole steadily acting combination of conditions results in a constant movement from one kind of animal or plant type to

another and to the establishment of divergent lines of this movement, these changes in type and lines always being in the direction of better adaptation or fitness to the conditions of life. Several recent discoveries based upon the experimental study of variation and heredity have much lessened the importance of natural selection as a species-forming agent. It still remains, however, the chief explanation of adaptation.

Artificial selection has much less in common with natural selection than popularly supposed. It depends, however, as natural selection does, upon the existence of variations and heredity and upon the culling out of certain individuals which are allowed to produce offspring while the great majority are not so allowed. This culling out, or selection, however, is made according to the needs and whims of man and not at all upon the basis of natural advantage or fitness. As a matter of fact most artificial selection is in the direction of unfitness for existence under natural conditions. Very few domestic races of animals could hold their own in nature.

In artificial selection, man, by being able to control matings exactly, has a means of modifying races much more rapidly than they are usually modified in nature. Man not only selects to live the individuals showing certain wished-for variations, but can mate together individuals which show these particular variations in highest degree. Or he can mate individuals showing different variations which he would like to combine. By taking advantage of the great present-day extension of our knowledge of the facts and laws of variation, inheritance, and selection the artificial breeder can work much more rapidly and with much more accuracy than ever before.

Segregation, or Isolation.—The modification of species either in nature, or under the hands of man, always includes as part of the process the segregation, or isolation, from the whole mass of individuals of a small number specially like each other. This is effected in natural selection by the saving of the few with advantageous variations and the death of the others; in artificial selection, by the culling out process of the breeder. These few saved or selected individuals breed together and are

the beginners of a new type within the species, that is, of a modification of it.

Such segregation can also occur in nature, and certainly often does, by the chance isolation by geographic barriers of a few individuals of a species, which are thus prevented from breeding miscellaneously with the other members of the species, but must breed together, thus tending to perpetuate their own variations and idiosyncrasies. Such geographical isolation has certainly led to the origination of many species modifications called geographic races or varieties, and with time and the cumulation of these modifications through many generations, to many actual new species.

It is possible also that certain physiological causes of the enforced mating together of certain few individuals, thus producing a sort of physiological segregation or isolation, may lead to species modification. Personal antipathies, separate times of coming to maturity, etc., may act as such agents of physiological segregation.

The Proof of Evolution.—Despite our statement at the beginning of this chapter that the fact of evolution is so generally accepted that there is no longer any discussion of its proofs, it may be advisable to state here succinctly on just what basis the general belief in evolution rests. This basis is that of the observed facts in four general biological subjects, namely, paleontology, comparative anatomy and physiology, embryology and development (ontogeny), and plant and animal geography.

By a study of animal fossils from all the different fossil-bearing strata of the earth's crust, it is evident that in the earliest geographical epochs only very simple animals lived, such as Protozoa, the simpler invertebrates, and, perhaps, a few simple Chordates. With the passing of time there came into existence more specialized or higher invertebrates, then the simplest true vertebrates, as the fishes and amphibians, and finally the higher kinds, as the reptiles, birds and mammals. The paleontological record is, in other words, plainly a record of organic evolution.

A careful comparison of the structure of different animals

shows such fundamental similarities as to indicate beyond doubt an actual blood relationship of wider or closer degree among them. The superficial differences among animals evidently of common identity of basic structural plan are exactly those which life under differing conditions would call for as helpful modifications or adaptations. This same condition of fundamental likeness with superficial differences is true also of the functions or physiology of animals.

A close study of the complete life history or development of an animal from beginning egg to full-grown adult condition, reveals the fact that this course of personal development shows striking similarities both with the paleontological record and with the revelations of comparative anatomy. Ontogeny is said to recapitulate phylogeny, by which is meant that each animal in its personal development runs through swiftly, but more or less obviously, a much abridged recapitulation of the stages of the evolution of the species to which it belongs.

Finally the facts of the present and past distribution of animals over the earth's surface reveal such striking conditions of close animal relationships accompanying the present or past continuity of land and water masses, and such wideness of relationship associated with long separated regions, that only the explanation of evolution is sufficient to account for these facts. In Australia, which is a great land mass long separated geographically from other continents, the animals, except such kinds as are spread by man unwittingly or intentionally, or are easily distributed by ocean currents, are of kinds very different from those elsewhere in the world. But in Africa and South America, which are more widely separated geographically but have been connected in geological periods not so very remote, there are many fairly close relationships among the animals of the two regions. The differences, also, are just about as great as the length of time of the actual separation of the two continents would make probable. By such zoo-geographic studies carried on for many kinds and groups of animals, and for many regions of the earth, a great army of facts has been collected which correspond perfectly with the theory of descent, *i.e.*, evolution.

Animal Ecology and Adaptations.—The relation of animals to their physical environment, and their inter-relations with other animals and plants, constitute a special phase of biologic study called animal ecology. As these special relations are associated always with special adaptive conditions of structure and function, the subject of ecology includes, in a way, the subject of adaptations, and thus comes with particular pertinence under the attention of the student of animal evolution.

The relations and varied adaptations of animals in connection with food getting, defense and offense, production and care of young, and similar other activities common to all animals but performed in extraordinarily various ways, are most stimulating subjects of investigation. As these adaptations are functional as well as structural, such subjects include the study of the behavior, instincts and intelligence of animals, and become thus directly related to the problem of the origin of our own instincts and intelligence. Among the various highly developed special adaptations of animals those of color and color pattern, of parasitism, and of different phases of mutual aid, offer unusually interesting subjects of special study, and may be introduced here by a few paragraphs.

Color is produced by the presence of pigment in the surface parts or by the structural character of the epidermal hairs, feathers, or scales with which the animal's body may be covered. By reflection and interference effects, due to the laminated or striated structure of these parts, brilliant metallic or iridescent colors are produced, such as the blues, purples and greens of the humming-birds, butterflies, fishes, etc. The most obvious use of the colors depends largely upon their arrangement into definite patterns and on the harmonizing of these color patterns with the environment in such a way as to make the animal more or less indistinguishable when at rest and thus hide it from its enemies. The phenomena of protective resemblance and mimicry are among the most highly developed and extraordinary of animal adaptations.

Some of the many curious conditions of structure, development and habit, developed in connection with the adoption of a parasitic life have already been described in this book.

Another kind of association among animals is that based on a greater or lesser degree of mutual aid derived from this association. It appears in two types, one exemplified by commensalism and symbiosis, in which two different kinds of animals live together temporarily or permanently to their mutual benefit or at least to the benefit of one kind and little or no injury to the other, and the other exemplified by a gregarious and social or communal life, in which a number of individuals of the same kind live together in temporary or permanent bands or in large family communities.

The first type is illustrated by the hermit crabs that carry colonies of hydroid polyps on their shells, the little crab being protected from enemies by the stinging threads of the polyps, while the sessile polyps gain an advantage by the crab's movements and probably by getting small bits from the crab's clumsy tearing up of its own food. Especially developed is the commensal relation between certain insects called ant-guests and the ants which serve as their hosts. Over 1500 species of insects, mostly small beetles and flies, live in the nests of various ants, some as robbers, some as tolerated parasites, and some as desired commensals. These latter provide the ants with certain kinds of special food produced by their bodies, and aid in cleaning both the nests and the ants themselves, while they in turn receive food from the storerooms of the ants, or even by regurgitation from their mouths.

Of the second type the life of the communities of the social wasps and bees and ants, already described in some detail elsewhere in this book, is the best example. The highly specialized communities of the honey-bee and of the ants are a splendid illustration of the possibilities and great advantages of adaptations based on the principle of mutual aid. It is of course the extreme development of the mutual aid factor in human life that makes man the highly successful and noble animal he is.

PART II

CHAPTER XXVIII

PARASITIC PROTOZOA CAUSING DISEASES OF MAN AND DOMESTIC ANIMALS

Parasites and Disease.—More than two hundred years ago it was known that small animal parasites were associated with and were the cause of certain diseases, and it soon came to be generally believed that all of our ills were in some way caused by such parasites, known or unknown. At first only the parasitic worms and other large parasites were known, but later it was discovered that many of the Protozoa and minute plant parasites, the bacteria, also caused many diseases. To-day we know definitely that such diseases as typhoid, cholera, tuberculosis and many others are caused by the presence of bacteria in the body and that such maladies as malaria, sleeping sickness, syphilis, and many fevers are caused by Protozoa.

Then there is a long list of other epidemic diseases, such as smallpox, measles and scarlet fever, the exact causes of which have not been determined. Many of these are believed to be due to micro-organisms of some kind, and if so these parasites will almost certainly sooner or later be found. Curiously enough most of the diseases in this last class, and many of those that are caused by bacteria, are contagious, while all that are caused by animal parasites are, as far as is known, infectious but not contagious. It is important that we keep in mind this distinction. By contagious diseases are meant those which are transmitted by contact with the diseased person, by touch, or by the breath or the effluvia from the body, or by the use

of the same articles. Smallpox, measles and influenza are examples of this group. By infectious diseases are meant those which are disseminated by contaminated water or food, or other infected substances introduced into the body in some way. Typhoid, malaria, yellow fever, and cholera, and others are examples of this class. Thus it is evident that all of the contagious diseases may be infectious, but most of the infectious diseases are not as a rule contagious, although some of them may become so under favorable conditions.

Just one example will show the importance of knowing whether a disease is contagious or infectious. Until a few years ago it was believed that yellow fever was highly contagious, and every precaution was taken to keep the disease from spreading by keeping the infected region in strict quarantine. This often meant much hardship and suffering and always a great financial loss. We now know that it is infectious only and not contagious, and that all this quarantine was unnecessary. The whole fight in controlling an outbreak of yellow fever, or in preventing such an outbreak, is now directed against the mosquito, the sole agent by which the disease can be transmitted from one person to another.

Definition of a Parasite.—A parasite is a living organism that lives in or on some other organism from which it derives its nourishment for the whole or a part of its existence. As a general thing we are accustomed to think of a parasite as working more or less injury to its host. As a matter of fact the number of parasitic organisms that are seriously detrimental to the welfare of their hosts is comparatively small while the number of parasites that do no appreciable harm, and of whose existence in the body the host is often not even aware, is large.

Diseases Caused by Amœbæ

Amœbic Dysentery.—A species of *Amœba, A. dysenteriæ*, is found associated with a disease of man known as amœbic dysentery. This disease occurs most commonly in tropical countries, but is sometimes met with in temperate zones. The amœbæ are found in the alimentary canal, usually in

the large intestine, where they produce serious ulcers or at least extend and prevent the healing of ulcers started from other causes. Amœboid organisms are found in the tissues of the brain in animals affected with hydrophobia, and similar organisms are found in the skin of smallpox patients, but it has not been shown that they cause these diseases. Several other *Amœbæ* may be found in various tissues or organs of men and many of the domestic animals, but they are usually regarded as harmless.

One species, *Amœba meleagridis*, is, however, the cause of a fatal disease of turkeys known as entero-hepatitis, or "blackhead." The disease is now spread throughout North America, and when once a farm has become infected no further attempts should be made to raise turkeys there, at least for some years. Turkeys become infected by swallowing the encysted amœbæ that have been distributed in the droppings from infested turkeys. Young turkeys may become infected from encysted amœbæ which adhere to the shells from which they hatch. In the alimentary canal of their host the amœbæ break from their cyst and cause ulceration of the intestine and abscess of the liver. Diarrhea soon begins, and in the later stages of the illness the head of the turkey turns black.

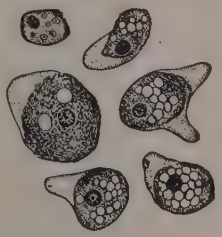

FIG. 147.—*Amœba dysenteriæ*. The two lower parasites are nearly filled with red blood corpuscles. The smaller spherical mass in the upper left corner is an encysted form. (Greatly enlarged; after Braun.)

The same *Amœba* often occurs in other birds, such as chickens, ducks, quail, pigeons, sparrows, etc., but it seldom causes serious trouble in any except turkeys, and young turkeys are much more susceptible than old ones. It is believed that sparrows have been an important factor in the spread of the disease.

There is no efficient remedy. Turkeys should not be allowed to run with other fowls and they should be kept only in uninfected places.

Sleeping Sickness and Other Diseases Caused by Trypanosomes

To the group of parasitic *Protozoa* known as trypanosomes belong some of the most important enemies of mankind. These elongated, spindle-shaped, delicate little organisms, are found in insects, reptiles, birds and mammals. Many of the most important species are conveyed from one vertebrate host to another by means of insects, the parasites often undergoing some stages of their development in the invertebrate host.

Fig. 148.—*Trypanosoma gambiense.* Various forms from blood and cerebrospinal fluid. (After Manson.)

Trypanosoma lewisi, a parasite of rats, is perhaps the best known, as it is always common wherever rats are found. These parasites are transmitted from rat to rat by the common rat-louse and probably also by rat-fleas. They do not seem to injure the rats. *Trypanosoma gambiense* is the most important member of this group, as it is the parasite that causes the disease known as sleeping sickness, a scourge that for the last few years has created more interest and

been more carefully studied than any other disease. It has spread rapidly over a large part of Africa, killing hundreds of thousands of the natives of these regions. The early symptoms of the disease are various, but infection is usually soon followed by fevers, and the patient gradually becomes anemic and physically and intellectually feeble, with an increasing tendency to sleep. As the stupor deepens the patient loses all desire or power of exertion and soon succumbs to the uncanny death.

Other animals beside man may be infected with this parasite, but it does not seem to injure them. The parasite is carried

FIG. 149.—Tsetse-fly. (After Manson; two and one-fourth times natural size.)

from one host to another by a species of tsetse-fly, *Glossina palpalis*, which resembles somewhat our common stable-fly. It is now known that another tsetse-fly, *G. morsitans*, is also an agent in the transmission of this disease. When the fly sucks blood from an infected animal some of the trypanosomes are taken into its body where they undergo certain changes, the fly usually not becoming infective until about three or four weeks later. It is then capable for a period of

four months or more of infecting any person or other animal that it bites.

G. palpalis is found only in tropical Africa and is limited in its distribution there to certain very definite, narrow, brushy areas along the water's edge. If these places can be avoided there seems to be little danger. Those who are fighting the disease have found that if the brush in the vicinity of watering-places and ferry-landings is cleared away such places become comparatively safe. These flies do not lay eggs but produce full-grown larvæ which soon pupate in the ground.

Trypanosoma cruzi is another species that causes a serious, often fatal, disease in Brazil. It is transmitted by the bug *Conorrhinus megistus*, belonging to the family *Reduviidæ*, order *Hemiptera*. This bug has habits very similar to those of the bedbug, inhabiting houses and biting sleeping persons. Kala azar, a chronic disease occurring in the Mediterranean region and in many places in Asia, is caused by a parasite, *Leishmannia donovani*, somewhat resembling the trypanosomes. The infection is probably acquired by the bite of an insect, perhaps a bedbug. A similar disease, called Delhi boil, occurs in the same region and also in Brazil, and it is thought that infection may be carried to a wound by house-flies.

There are several diseases of domestic animals caused by trypanosomes. Tsetse-fly disease, or nagana, is one of the most serious scourges of domestic animals in Central and Southern Africa. In some sections it is almost impossible to keep any kind of imported animals on account of this disease, which is caused by *Trypanosoma brucei*. This parasite is to be found in several different kinds of native animals which seem to be themselves practically immune but are always a source of danger when non-immune animals are introduced. The tsetse-fly, *Glossina morsitans*, one of the most dreaded insect pests of Southern Africa, is largely responsible for the transmission of this disease, but one or two other species of tsetse-flies may also act as hosts for the parasite. All through Asia, in parts of Africa and in the Philippines there is a very serious disease of horses and cattle known as surra. This disease, which also affects camels, elephants, buffaloes and dogs in

regions where it occurs, is caused by *Trypanosoma evansi* and is probably transmitted by the bites of stable-flies (*Stomoxys*) and horse-flies (*Tabanidæ*).

In 1906 some cattle that had been imported into America from India for experimental purposes were found to be infected by the parasite which causes this disease. Fortunately this discovery was made while the cattle were still in quarantine. All those infected were destroyed and the disease thus stamped out before it had a chance to spread. A disease similar to both nagana and surra, and known as murrina, has recently been found affecting horses and mules in Panama. It is caused by *Trypanosoma hippicum*. It is believed that the parasite is carried mechanically from one host to another by flies that visit the sores due to wounds of various kinds on the animals.

Dourine, or *mal du coit*, is a serious disease of horses that has been introduced into North America, where it appears from time to time in widely separated parts of the west. It is caused by *Trypanosoma equiperdum*, and is transmitted during breeding, perhaps rarely by bites of flies or fleas. As soon as infected animals are discovered they are destroyed, and the disease is now almost or quite stamped out. *Trypanosoma equinum* causes a deadly disease of horses, known as *mal de caderas*, in Brazil and other parts of South America.

Several other species of trypanosomes are found in wild and domestic animals. Almost any of these may at any time become of more or less economic importance when susceptible, non-immune animals are brought into the regions where the parasites occur, or when the parasites by some means are introduced into new regions.

Relapsing Fevers and Other Diseases Caused by Spirochætes

The spirochætes are very minute, thread-like parasites closely related to the trypanosomes. They occur in shellfish and in the alimentary canal or blood of certain fish, birds and mammals where they apparently do no harm, but some

produce diseases in man and other animals. The most important of these are the relapsing fevers of which there are

FIG. 150.—Relapsing fever tick, *Ornithodorus moubata*. (About four times natural size.)

FIG. 151.—The fowl-tick, *Argas persicus*. (About four times natural size.)

several types caused by as many different species of *Spirochæta*. The relapsing fever of Africa, or African tick fever,

is one of the most dreaded of these. It is caused by *S. duttoni*, and is transmitted by the bite of a common African tick, *Ornithodorus moubata*, which has habits similar to those of the bedbug. The relapsing, or remittent fever of Europe is caused by *S. recurrentis*, and is probably transmitted by some blood-sucking insect, possibly by the bedbugs. The relapsing fever of America is caused by *S. novyi*. The mode of infection is not definitely known. Yaws, a disease of the tropics which is characterized by numerous ulcerating sores on the body, is caused by *Spirochæta pallidula*. It is thought that the common house-fly plays an important part in its dissemination. Of the diseases of domestic animals caused by spirochætes a fatal disease of fowls known as spirochætosis is the most important, as it may kill all the fowls in the chicken yard in the course of a few days. It is caused by *Spirochæta marchouxi* (*gallinarum*) and is transmitted by ticks, usually by the common chicken tick, *Argas persicus*.

Syphilis.—To the genus *Treponema* belongs a single important parasite, *T. pallidum*, that used to be classed with the *Spirochæta*. It is the cause of that terrible disease, syphilis, which results in untold suffering not only among those individuals who are responsible for its dissemination but among many innocent persons as well. Much of the syphilitic disease that is in the world to-day is due to the infection of infants before or at the time of their birth.

Malarial Fevers and Other Diseases Caused by Sporozoa

The *Sporozoa*, or spore-forming *Protozoa*, include the smallest but by no means least important members of the branch. They are all parasitic and vary greatly in appearance, organization and life history. They are so very plastic that they can adapt themselves readily to their various hosts. Some of them live during some stages of their development in the blood cells of man and other vertebrates, the rest of their life being passed in insects or other invertebrates. Malarial fevers are caused by such parasites. Those that occur in man belong to the genus *Plasmodium*. The three most important species are

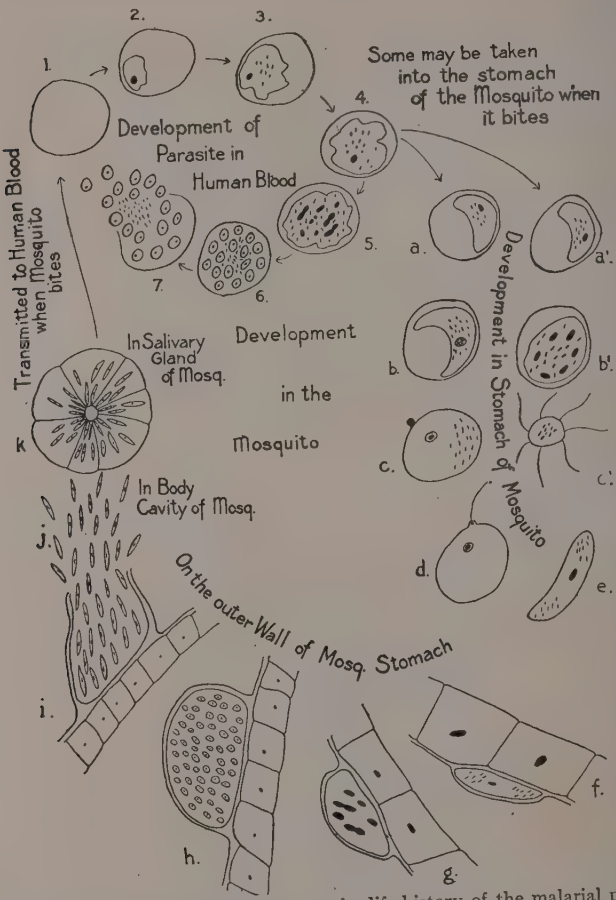

FIG. 152.—Diagram to illustrate the life-history of the malarial parasite. 1 is a red blood corpuscle; 2 to 7 show the development of the parasite in the corpuscle; *a b c d* and *a' b' c'* and *e* the development of the parasite in the stomach of the mosquito; *f g h i* the development in the capsule on the outer wall of the stomach of the mosquito, *k* in the salivary gland.

vivax, *malariæ* and *falciparum*, causing respectively the tertian, quartan and remittent types of malarial fever in man.

The life history of all of these is very similar, the principal difference being in the length of time it takes them to sporulate. Let us begin with the parasite after it has been introduced into the blood and trace its development there. At first it is slender and rod-like in shape. It has some power of movement in the blood-plasma. Very soon it attacks one of the red blood-corpuscles and gradually pierces its way through the wall and into the corpuscle substance; here it becomes more amœboid and continues to move about, feeding all the time on the corpuscle substance, gradually destroying the whole blood cell. As the parasite feeds and grows there is deposited within its body a blackish or brownish pigment known as melanin.

During the time that the parasite is feeding and growing it is also giving off waste products, but as the parasite is completely inclosed in the corpuscle wall these waste products cannot escape until the wall bursts. After about forty hours, if the parasite is *vivax*, or about sixty-five hours if it is *malariæ*, it becomes immobile, the nucleus divides again and again and the protoplasm collects around these nuclei, forming a number of small cells, or spores, as they are called. In about forty-eight or seventy-two hours, depending on whether the parasite is *vivax* or *malariæ*, the wall of the corpuscle bursts and all these spores with the black pigment and the waste products that have been stored away within the cell are liberated into the blood-plasma.

These spores are round or somewhat amœboid and are carried in the blood-plasma for a short time. Very soon, however, each one attacks a new red corpuscle and the process of feeding, growth and spore-formation continues, taking exactly the same time for development as in the first generation, so that every forty-eight hours in the case of *vivax*, and every seventy-two hours in the case of *malariæ*, a new lot of these spores and the accompanying waste products are thrown out into the blood. Thus in a very short time many generations of this parasite occur, and thousands or hundreds of thousands of the red blood corpuscles are destroyed, leaving the patient weak

and anæmic. It will be seen, too, that the recurrence of the chills and fevers is simultaneous with the escaping of the parasites from the blood corpuscles, together with the waste products of their metabolism. These waste products are poisonous, and it is believed that this great amount of poison poured into the blood at one time causes the regular recurring crisis.

FIG. 153.—Malarial mosquito, *Anopheles maculipennis*, on the wall. (About six times natural size.)

We have already learned that such a process of asexual reproduction cannot go on indefinitely, but for a long time those who were studying these parasites were at a loss to know where the sexual stage took place. Many men have worked on this problem but perhaps most credit will always be given to Ronald Ross, a surgeon in the English army, who, after many months of continuous labor, finally demonstrated that the

sexual stage of the development of these parasites takes place in the stomach of the mosquito.

It was found that certain of the parasites in the blood do not go on with their development there. When these particular parasites are taken into the stomach of most mosquitoes they are digested with the rest of the blood. But when they are taken into the stomach of mosquitoes belonging to the genus *Anopheles*, or other closely related genera, they are not digested but go on with their development. Conjugation takes place, resulting in the production of a new form of the parasite, the zygote, that makes its way through the walls of the stomach on the outside of which it forms a little nodule. Within these nodules further division and development takes place, until finally the nodules burst open and many thousand minute rod-like organisms, sporozoites, formed by the repeated division of the zygote, are turned loose into the body cavity of the mosquito. Owing to some unknown cause these little organisms collect in the large vacuolated cells of the salivary glands of the mosquito, and when the mosquito bites a man they pour down through the ducts with the secretion into the beak and are thus again introduced into the human circulation.

The nodules, or cysts, on the walls of the stomach of the mosquito may contain as many as ten thousand sporozoites, and as many as five hundred cysts may occur on a single stomach.

It takes ten, twelve, or more days from the time the parasites are taken into the stomach of the mosquito before they can complete their transformations and reach the salivary gland, the time depending on the temperature. So it is ten or twelve days, or sometimes as long as eighteen or twenty days, from the time an *Anopheles* bites a malarial patient before it is dangerous or can spread the disease. On the other hand, the sporozoites may lie in the salivary gland alive and virulent for several weeks. All the parasites are not given up at one time, so that three or four or more people may be infected by a single mosquito.

The findings of Ross have been verified many times, and many experiments have proven beyond any doubt that this is

the only way in which malaria is transmitted, and that the low-lying lands or swamps have nothing whatever to do with malaria except in so far as they furnish a breeding place for mosquitoes. Much less, then, can the mists or bad air—*mal aria* in the Italian—produce malaria. Without mosquitoes there is no malaria.

Texas Fever of Cattle

To the genus *Babesia* (formerly known as *Piroplasma*) belong several species of blood parasites that are of great economic importance. In the vertebrate host they live in the

Fig. 154.—Texas fever tick, *Margaropus annulatus*, young adult not fully gorged. (About four times natural size.)

red blood corpuscles, and they are transmitted from one animal to another by means of ticks. The most important of the diseases caused by the members of this genus is a disease of cattle known in the United States as Texas fever, or tick fever, or splenic fever. It occurs in nearly all tropical and subtropical and in many temperate regions, and outside of the United States is more commonly known as "red water." In the United States it causes an annual loss estimated at $100,-

000,000, and in many parts of the world it is almost impossible to keep cattle because such a large per cent. of them die of the disease. The parasite, *Babesia bigeminum*, that causes the disease is transmitted by the common cattle tick, or Texas fever tick, *Margaropus annulatus*, in the United States, and by closely related species in other countries. The infection is not direct, that is, the tick does not feed on one host, then pass directly to another, carrying the disease germs with it. Unlike many other ticks the Texas fever tick does not leave its host until it is fully developed. When the female is full grown and gorged she drops to the ground and lays from 1000 to 4000 eggs from which the minute "seed ticks" soon hatch. These make their way to some nearby blade of grass or shrub and at the first opportunity attach themselves to any cattle that may pass that way.

If the mother tick feeds on an animal that is infected with Texas fever some of the parasites that she takes into the body will find their way into her eggs, and the young ticks that hatch from these will be infected and ready to transmit the disease to their host.

It has been found that the Southern cattle in the regions where the ticks occur normally usually have a mild attack of the disease when they are young, and although they may be infected with the parasite all the rest of their life it does not affect them seriously. But these cattle are a source of danger when taken into a region where the ticks do not occur naturally, for the larvæ that issue from the eggs laid by the infected adult ticks may attack non-immune cattle which soon sicken and die.

At present in the United States no cattle south of a certain quarantine line are allowed to be taken north except under very strict regulations. It has been demonstrated that by a system of feed-lots and pasture rotation many infested regions may be made perfectly safe. The aim is to let all of the ticks drop to the ground on land where they may be destroyed or left to starve. When it is necessary to treat cattle that are badly infested with ticks, large vats are built and filled with a dipping solution and the cattle are then driven through it. Many different kinds of solutions have been used for this pur-

pose. One should consult some of the Government or Experiment Station Bulletins (see page 419) for directions for making and using these.

Similar diseases caused by other species of the genus *Babesia* occur in horses, sheep, dogs and other animals, but none is so important as the Texas fever of cattle.

Other Protozoan Diseases

Spotted Fever.—Spotted fever, or Rocky Mountain fever, is a disease that occurs in the mountains in the northwestern United States. It is transmitted by ticks, *Dermacentor venustus*, and is supposed by many to be due to an organism closely related to, or belonging to the genus *Babesia*. It has been shown that domestic animals, particularly the larger ones, in the region where the fever occurs, are the principal hosts for the adult ticks, so if these animals can be kept free from ticks, by dipping and otherwise, the disease can be largely controlled.

Pebrine of Silkworms.—About the middle of the nineteenth century a strange malady appeared among the silkworms in Southern France and caused enormous losses. The silk growers knew nothing of the nature of the disease, and were at a loss to know how it spread, for even though they placed the eggs of the silk-worm moth in perfectly clean places and took the very best care of the larvæ, the silk-worms would suddenly sicken and die at a certain stage of their development. Pasteur, who was then just beginning his great work, made a careful study of the disease and discovered that it was caused by a sporozoan. It was found that this parasite, now known as *Glugea* (*Nosema*) *bombycis*, was so minute that it would enter the eggs before they were laid by the moth, so that the larvæ were affected from the time they hatched, although the disease did not manifest itself until a later stage in their development. The disease is known as pebrine, and was the first disease proved to be due to an infection by a Protozoan parasite. In several countries where silk-worm growing is an important industry, Government experts now examine all the eggs that are used for hatching and only those that, by

microscopical examination, are shown to be free from the parasite are sent to the growers.

Epidemics Among Fishes.—Sometimes in the United States, and more frequently in Europe, destructive epidemics appear among the fishes in lakes or rivers. Hundreds of thousands of fish may die and be washed upon the shores and the particular species attacked may be almost exterminated in some regions. The diseases responsible for these epidemics are caused by various species of *Myxosporida*, which attack and destroy the tissues of their hosts, often causing many serious tumors over the body. Young fish are especially apt to suffer from the attacks of these parasites.

Diseases Caused by Invisible Microorganisms

There are a number of diseases the causative agents of which are not yet definitely known. Nevertheless it has been demon-

Fig. 155.—Stable-fly, *Stomoxys calcitrans*, after engorging itself with blood. (About three times natural size.)

strated that many of these are caused by living organisms, probably too small to be seen by any microscopes that have yet been invented. More refined microscopic methods may sometime reveal some of these to us, and we may then be able to determine their relation to other known forms.

That yellow fever is caused by such an organism has been definitely shown, and although we do not know the parasite

we know much of its life-history, and certain investigators do not hesitate to express their belief that it belongs to the genus *Spirochæta*. Yellow fever is transmitted only by the yellow fever mosquito.

Infantile paralysis, or poliomyelitis, is also caused by one of these[1] ultra-microscopic parasites, which can probably be distributed, as recently indicated by experiments with monkeys, by the common stable-fly, *Stomoxys calcitrans*. The disease seems also to be directly contagious.

Cattle plague, canine distemper, swamp fever of horses, hog cholera and several other diseases also belong to the group produced by invisible parasites. Some of them will probably be found to be caused by animal parasites, others by bacteria.

[1] It has recently been found to be visible in certain stages, although invisible in others.

CHAPTER XXIX

INSECTS AND DISEASE

We have already learned (Chapter XXVIII) that insects are the necessary hosts of the parasites that cause some of our worst diseases, and that the spread of these diseases depends wholly on the presence of the infected insects. It is only during the present century that the very great importance that insects thus bear to our health has been realized, and many of the most important recent discoveries in medical science have had to do with this relation of insects to some of the common scourges that afflict man or his domestic animals.

Since it was shown beyond all doubt that malarial fevers depend wholly on the presence of infected mosquitoes (page 361), successful efforts have been made to control these insects in some of the places where the disease was most common. As mosquitoes breed only in quiet water the problem of control is not as great as it would at first appear to be, and there is now no reason why almost any community should not rid itself of these disease-bearing pests. In temperate regions malaria is not as fatal as it is in the tropics where it is the cause of one-fourth to one-half of all the sickness. Yet it has been estimated that the annual monetary loss due to sickness from malaria in the United States is many millions of dollars. The suffering and misery, the loss of vitality of young and old, and the death of twelve thousand persons each year, are results of malaria the importance of which cannot, of course, be stated in dollars and cents.

Almost every day there is an increase in the evidence that shows how dangerous are such common and long tolerated household pests as house-flies and their near relatives, the stable-flies, flesh-flies and others. That these insects do aid in the dissemination of certain of our germ-caused diseases, as typhoid

and tuberculosis, is sure. That they may aid in distributing others is highly probable. Mosquitoes and house-flies will be feared in the not far distant future as venomous snakes are now. And they will be fought even more vigorously, for their abundance makes them immensely more dangerous.

Life History and Habits of Mosquitoes.—Mosquitoes lay their eggs in water, or in places where water is apt to accumulate. Some species fasten the eggs together in little masses that float on the surface and look like small particles of soot at

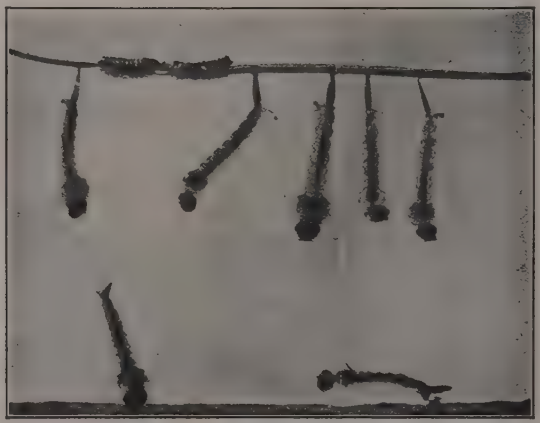

FIG. 156.—Mosquito eggs and larvæ, *Theobaldia incidens;* two larvæ feeding on bottom, others at surface to breathe. (Enlarged.)

first glance. Other species lay their eggs singly, some floating about on the surface of the water, others sinking to the bottom where they remain until the young issue. In the summer time the eggs hatch in thirty-six to forty-eight hours. The larvæ, or "wrigglers," are fitted only for aquatic life, but they must obtain their oxygen directly from the air and so have to come to the surface to breathe. This is an important thing to remember when considering means for their control. The larvæ of most mosquitoes have, on the eighth abdominal seg-

ment, a rather long breathing tube, the tip of which is thrust just above the surface of the water when they come up to breathe. Other larvæ do not have such a breathing tube, the spiracles which open into the trachea being situated on the surface of the eighth segment. The pupæ of all species are active but take no food. The two trumpet-shaped breathing tubes of the pupæ are situated on the thorax, and when the pupæ come to rest these extend just above the surface of the water. When the adult is ready to issue the pupal skin splits along the back and the mosquito slowly comes forth, usually

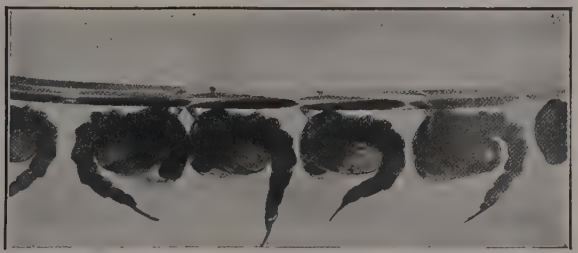

FIG. 157.—Mosquito pupæ, *T. incidens*, resting at the surface of the water. (Enlarged.)

resting for a short time on the cast-off pupal skin until the wings become dry and firm enough to use.

Malaria-carrying Mosquitoes.—In the United States only mosquitoes belonging to the genus *Anopheles* carry malaria, so it is important to be able to distinguish the members of this genus in their various stages. The eggs of *Anopheles* are laid singly, but are often found together in groups of three or four floating on the surface of the water. Each egg is provided with characteristic membranous expansions on each side near the middle. These keep the eggs afloat. The larvæ feed largely on minute plants or other organisms at the surface of the water, and when feeding lie nearly horizontally, with the body touching the surface at several points. The absence of a breathing tube, and this habit of always lying with the body parallel to the

surface of the water when feeding or at rest, readily distinguish these larvæ from those of any of the non-Anopheline, or non-malarial, mosquitoes. The pupæ are, however, not so easy to distinguish. The adults of *Anopheles* have spotted wings, a character which only a few of our other mosquitoes have. With most mosquitoes the maxillary palpi of the male are long and those of the female very short, but the *Anopheles* mosqui-

FIG. 158.—A female mosquito, *T. incidens;* note the thread-like antennæ. (Three times natural size.)

toes have the palpi long in both sexes, so any female mosquito with long maxillary palpi is an *Anopheles*. The males of all mosquito species may be readily distinguished from the females by the big feathery antennæ (see Fig. 159). The antennæ of the female are provided with only a few hairs. When an *Anopheles* mosquito is resting on the wall or ceiling, its body is held at an angle with the surface on which it is standing, as shown in Fig. 163. Other mosquitoes rest with their

bodies nearly parallel to the surface on which they are standing. (Compare Figs. 162 and 163.)

FIG. 159.—A male mosquito, *T. incidens;* note the feathery antennæ (Three times natural size.)

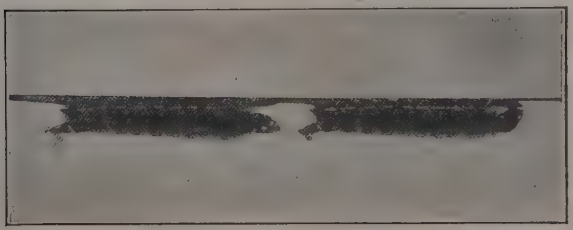

FIG. 160.—*Anopheles* larvæ, the one to the right feeding. (Enlarged.)

Mosquito Control.—Mosquitoes, in all stages of their development, have many natural enemies, most important of which are fish and various aquatic insects that feed on the larvæ

and pupæ. But often the eggs are laid in water where none of the natural enemies occurs, and they then breed undisturbed.

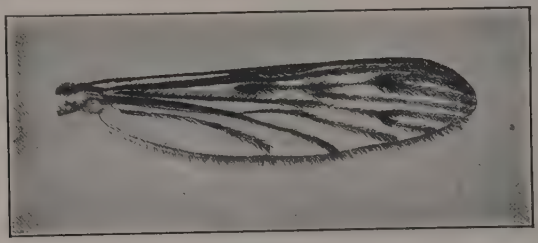

FIG. 161.—Wing of *Anopheles maculipennis*. (Eleven times natural size.)

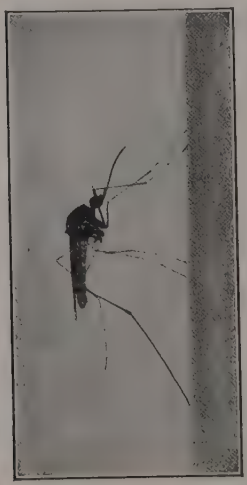

FIG. 162.—A non-malarial mosquito, *Theobaldia incidens*, male, standing on the wall. (About twice natural size.)

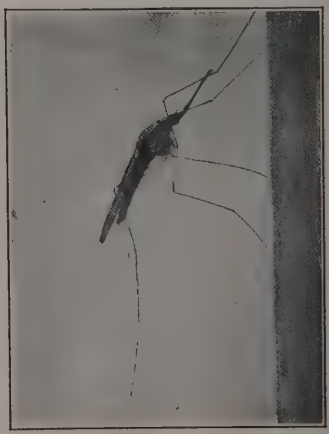

FIG. 163.—A malarial mosquito, *Anopheles maculipennis*, female, standing on the wall. (About twice natural size.)

Such places require careful attention when fighting mosquitoes. All water troughs and barrels or cisterns should be emptied

frequently, or be kept covered so that the mosquitoes cannot get to the water in them. All tin cans, or other scattered receptacles that might hold a little water, should be removed or placed so that water will not stand in them. Small ponds should be drained or kept covered with a film of oil during the summer time. Larger ponds are usually naturally stocked with fish, predaceous insects and other enemies of mosquito larvæ and pupæ, so that they are not a source of danger unless the margins are filled with rushes or other strong plant growth. Mosquitoes will not breed in running streams, but the quiet pools along the sides may afford excellent breeding places, particularly if they are cut off from the rest of the stream. Many species breed abundantly in wet pastures or meadows, and others abound in the brackish tide pools in the marshy land along sea-coasts. Such marshes must be drained or dyked so the water will not remain on them, or all the little pools must be covered with oil if such regions are to be freed from these pests.

Yellow Fever and Mosquitoes.—For many years the cause and method of dissemination of yellow fever was a puzzle to physicians and scientists. The disease was always regarded as highly contagious as well as infectious, and every effort was made to isolate patients and to establish strict quarantines in infected regions. But all such methods proved unsatisfactory. Many people became ill without ever having been near a yellow fever patient, while others worked in daily contact with sick persons yet did not take the disease.

During the American occupation of Cuba in 1900 yellow fever became very prevalent there and a board of army medical officers, known as the Yellow Fever Commission, was appointed to study the disease and try to find some means to control it. Some years previously a physician had suggested that a certain species of mosquito, *Stegomyia fasciata* (*calopus*), which was always found in regions where the yellow fever occurred, might be concerned in the transmission of the disease. The Yellow Fever Commission early decided to put this theory to the test, and before their experiments had been finished it was shown that yellow fever was transmitted by this mos-

quito and in no other way. Since that time many other experiments have been made, and it is now definitely known how this disease spreads through an infected region. The virus that causes the fever occurs in the blood plasma of the human host, but the yellow-fever patient is a source of infection for the mosquito only during the first three or four days after the fever manifests itself. The virus must undergo an incubation period of twelve to fourteen days in the mosquito before she is capable of transmitting the disease. After this incubation period the mosquito is infective for the rest of her life. The parasite

FIG. 164.—Yellow-fever mosquito, *Stegomyia fasciata*. (About eight times natural size.)

that causes the disease has never been seen, probably because it is too small, but it is believed that it is one of the large group of Sporozoan parasites.

One of the members of the Yellow Fever Commission died of yellow fever during the course of the experiments, and another member contracted the disease but recovered. The application of the knowledge gained by these studies enabled the officers soon to check the epidemic of yellow fever then existing in Cuba. A few years later when the disease appeared in virulent form in New Orleans it was stamped out in a remarkably short time by waging a ceaseless war against the mosquitoes. The Panama Canal Zone has long been regarded as one of the worst regions in the world for yellow fever and malaria. Since the United States began work on the Canal persistent efforts have been made to control the mosquitoes there. These efforts have been so successful that there has been no yellow fever in the Canal Zone for several years, and cases of malaria are comparatively rare.

The yellow-fever mosquito is a domestic insect. It is seldom found far from human habitation and for this reason can be comparatively easily controlled, for if every possible breeding place within a few hundred feet of every house was properly cared for this mosquito would no longer be present.

Fleas and Plague.—Plague is a disease that for ages was regarded as one of the greatest of human scourges, because when once started in a region there seemed to be no way to stop its ravages. But it, too, has been conquered within the last decade by the discovery of the cause of the disease, and the way in which it is transmitted from one host to another.

Plague is primarily a disease of rats and other rodents, and it is commonly spread by the fleas with which these animals are always infested. When a rat dies of the plague the fleas which have been sucking its blood leave it for some other host. As most of the rat-fleas will also bite man the infected fleas may communicate the disease to him.

The disease is caused by the presence in the blood of a bacillus, *Bacillus pestis*. There are several types of plague distinguished by the way in which they affect the patient, and they are probably spread in different ways. The bubonic plague is the most common. It may occur as sporadic cases among animals and be transferred from them to man by fleas. Under favorable conditions this type may become epidemic. Pneumonic and septicæmic plague are more virulent types, and may be transmitted directly from man to man and probably also conveyed by insects.

In the efforts to control the last outbreak of plague that occurred in the United States the whole fight was directed against the rats that had the disease and against the fleas that carried the infection to man. Hundreds of thousands of rats were killed, their breeding places destroyed, warehouses and storerooms made rat-proof, covered garbage cans were required in every yard, and many other measures were taken to make it impossible for rats to exist in any great numbers in the infested region. In this way there was stamped out in a remarkably short time an epidemic which might at an earlier time have proved a national calamity. In some places ground-squirrels

have become infected with the plague, and the Government is now waging a war against them in order that the disease may not be kept alive in them and again become epidemic among rats and man.

There are four species of fleas occurring in the United States that are commonly found on rats. Two of these are also common pests of man, and the others do not hesitate to bite man when they have a chance, so that all may transmit the plague from diseased rats to human beings. The cat and dog-

FIG. 105.—Human-flea, *Pulex irritans*; female. (Twenty times natural size.)

flea, *Ctenocephalus canis*, is probably the most common of them. It occurs in all places where cats and dogs are kept, and is often more common in houses and a worse pest than the human-flea, *Pulex irritans*, which is always a troublesome and persistent biter. The common rat-flea of the United States, *Ceratophyllus fasciatus*, and the Indian rat-flea, or plague-flea, *Xenopsylla* (*Læmopsylla*) *cheopus*, are not so troublesome to man.

As fleas breed in the dust under the carpets, in the cracks of

the floors, and in the sleeping places of cats and dogs, all these places must be thoroughly cleaned when a house becomes infested with fleas. Fleas are less apt to be troublesome in houses where rugs are used instead of carpets, as the rugs are more often taken outside for dusting and the floors more thoroughly cleaned. Mats that can be easily cleaned should be provided for the sleeping places of dogs and cats, and these animals should of course be kept out of doors. Benzine, naphthaline, pyrethrum and other substances are sometimes used against fleas, but the results are not wholly satisfactory. It is possible to kill all of the insects in the house by fumigation, but fumigating is dangerous unless done by an experienced person.

House-flies.—Until a few years ago the house-fly was looked on as a harmless, although somewhat troublesome, household pest, and was even regarded with some favor as it was supposed that it was of service as a scavenger. But careful studies of the insect and its habits have taught us to regard it in quite a different light, and it is now regarded as one of the most dangerous insects. It is hard to conceive of a better carrier of small particles of filth and germs, or one with better opportunities for collecting and distributing them. Almost every part of its body, and almost all of its habits, particularly adapt it for the picking up and distribution of filth and germs. The whole body is provided with a covering of spines and short soft hair in which particles of dirt are easily carried. The blunt end of the proboscis by which the fly sucks up its liquid food is provided with numerous ridges and depressions so that some of the material on which the fly is feeding is carried from one article of food to another. The legs are particularly hairy, and the last segment of each of the feet is furnished with two little pads which are covered with innumerable closely-set hairs that secrete a sticky substance. It is the presence of these hairs on its feet that enables the fly to walk on smooth perpendicular surfaces, such as the windowpane, or on the ceiling, and, incidentally, to carry along samples of the filth through which or over which it walks.

Ninety-eight per cent. of the house-flies lay their eggs in horse

manure, the others breeding in cow manure, human excrement or other filth. Each female lays from 120 to 150 eggs at a

FIG. 166.—The house-fly, *Musca domestica.* (Eight times natural size.)

time, and may lay five or six batches of these at intervals of a few days. These eggs hatch in ten to twenty-four hours, and

the whitish maggots feed and grow in the filth for three or four days before changing to the quiescent pupal stage which lasts four or five days longer. Then the adult fly issues. Some of the filth through which the fly has to crawl as it issues from the pupa inevitably clings to the little brush-like feet and the hairy body. If the flies bred only in stable manure and flew directly from the stable to the house there would be comparatively

FIG. 167.—Head of house-fly, showing eyes, antennæ and mouth-parts. (Much enlarged.)

little reason to complain, at least from a sanitary standpoint, for the amount of filth they carry from the barnyard to our food would be of little consequence. Too often, however, they visit other places before calling on us, and, unfortunately, these other places are often most unclean. Experiments have shown that when the fly walks over germ-infected material many of

the germs are carried and distributed to other substances over which it may walk, and that bacteria may live in the alimentary canal of the fly and even increase in numbers there and remain virulent in the excreta, or "fly specks," for as long as twenty days after these specks have been deposited. It has been shown also that larvæ of flies may feed on bacteria and the same organisms be recovered from the adult flies which develop

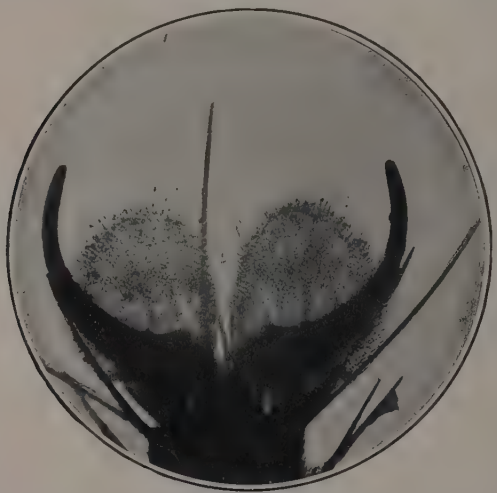

FIG. 168.—Foot of house-fly, showing claws, hairs, pulvilli and the minute clinging hairs on the pulvillæ. (Greatly enlarged.)

from the larvæ. All this indicates some of the possible ways in which flies may carry filth or disease germs from their dangerous breeding or feeding grounds directly to foods which may be exposed in the market place, dairy, or home.

It has been proved beyond a doubt that flies play an important part in the dissemination of typhoid germs, and it has also been shown that they carry some of the germs that cause the sickness and death of many babies, especially bottle-fed babies. Time and again it has been noted that outbreaks of

enteritis and other intestinal diseases occur during fly time, and a moment's thought, in the light of our knowledge of the habits of flies, will show how easy it is for the milk to become infected around dairy barns or milk wagons where the flies are always found in great numbers. It is quite possible, too, that flies may sometimes be concerned in the transmission of the germs

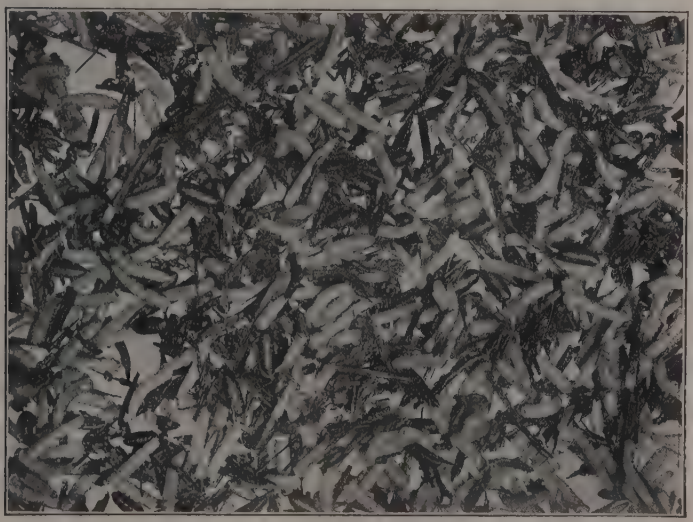

FIG. 169.—Larvæ and pupæ of house-fly, *Musca domestica*, in manure. (Natural size.)

that cause tuberculosis, influenza and other dreaded diseases. Of course only a small proportion of the flies carry disease germs, but they are all filthy, and it is impossible, without careful laboratory analysis, to distinguish those which carry disease from those which are merely dirty.

The only safe thing to do is to banish them all, not only from the house and the market place, but from the storerooms and dairies and all other places where food of any kind may be

exposed. Screens, sticky fly paper, fly poisons and fly traps about the house will give some relief, but there is little use in protecting the food after it has entered our homes if in the stores or markets or dairies it has already been exposed to contamination by thousands of flies that have visited it there. The problem is a larger one than simply keeping the flies out of our houses; larger but not more difficult, for the remedy is simple, effective and inexpensive. If the manure in which the flies breed is hauled from the barn at least once a week and scattered thinly over a field, it will dry so quickly that the flies will not breed in it. If it is impracticable to scatter the manure at once, it should be composted at least half a mile from any dwelling. Most livery stables have the manure removed daily, but few of them are careful to see that the bins or other places where the manure is stacked before being hauled are thoroughly clean. Thus there is left in cracks or corners enough manure to serve as breeding places for hundreds of thousands of flies. Then, too, few stablemen take the care to clean the stalls as thoroughly as they should, and many a one is surprised when he finds that the flies are breeding abundantly in the stalls which he considered sufficiently cleaned. Finally, after every effort has been made to clean up the breeding places of flies, our attention should be turned to trapping or poisoning the few flies that may still appear. Many more or less efficient fly traps are on the market, some of which, if properly baited, do really good work. Fly papers are often quite effective, but they are disgusting unless kept out of sight. A poison made by adding one tablespoonful of formaldehyde to one-half a pint of milk and water forms a very attractive bait and a deadly poison for the flies. The best way to use it is to place a piece of bread in a saucer and almost cover it with the poison, milk and water.

The Stable-fly, or Biting House-fly.—This is another fly that is commonly found in houses. It looks very much like the common house-fly, and only a close observer will notice the difference between the two. The most noticeable and important difference is in the character of the mouth parts. The tip of the proboscis of the house-fly is blunt and roughened, fitted

for rasping and reducing to a liquid or semiliquid condition the material upon which it feeds. The mouth parts of the stable-fly, on the contrary, form a strong piercing beak which can cut through even the toughest skin in order that the fly may suck the blood of its victim. Persons are often bitten by flies that they believe to be house-flies. But house-flies cannot bite, and it will usually be found that the culprits are stable-

FIG. 170.—Stable-fly, *Stomoxys calcitrans*. Resembles house-fly in general appearance, but has pointed, piercing and sucking beak, and the vein which terminates near the tip of the wing is not so sharply angulated as in the house-fly. (See Fig. 166.) (Five times natural size.)

flies. If the wings of a house-fly and a stable-fly be carefully compared it will be seen that the fifth vein (counting from the front margin) of the house-fly's wing is bent forward at a considerable angle while the corresponding vein in the wing of the stable-fly is only slightly curved. The fourth and fifth veins are the two veins that end near the tip of the wing. In the house-fly the tips of these veins are very close together; in the stable-fly they are rather widely separated.

The stable-flies develop in much the same way, and under the same conditions as the house-flies, but they are more apt to be found in cow manure or old straw or other decaying vegetation, than in horse manure. The stable-fly also takes longer to complete its development than does the house-fly, often requiring three or four weeks to pass through the larval and pupal stages.

Stable-flies are among the most serious pests of cattle and horses, biting them severely and causing considerable swellings in the places where they bite. They have recently been the subject of particular study and investigation because they have been suspected of being intimately connected with the distribution of that mysterious disease known as poliomyelitis, or infantile paralysis. This disease, which has been slowly spreading over America as well as most European countries, has baffled the skill of physicians because they have been unable to determine how it is transmitted. Experiments have been made which show that stable-flies are capable of transmitting the disease if they are allowed to bite first an infected and then a healthy monkey. While this by no means proves that it really spreads the disease among human beings, it yet adds greatly to the evidence against this insect, so that the flies should be destroyed whenever possible. The same measures that are necessary for the control of the house-fly would aid materially in controlling this insect also.

Other Diseases Carried by Insects.—There are many other diseases that are known to be transmitted by insects. Sleep-

FIG. 171.—Filaria in the thorax, head and labium of a mosquito. (After Castellani and Chalmers.)

ing sickness and other diseases caused by trypanosomes and carried by tsetse-flies have been discussed in Chapter XXVIII, and in Chapter XII it has been shown how mosquitoes carry

the filaria that cause elephantiasis. Mosquitoes are also probably responsible for the spread of dengue or break-bone fever. We do not yet know the organism that causes the disease, but experiments have shown that it can be spread by *Culex fatigans*, and possibly by other species of mosquitoes.

For a long time the theory that pellagra is in some way associated with the eating of maize has been generally accepted. Recently Dr. Sambon has suggested that pellagra may be caused by some organism that is transmitted by certain small black flies belonging to the family *Simulidæ*. This theory is not yet firmly established and there are many who do not accept it at all. The investigations that are now being carried on will doubtless soon settle the question. The black-flies are very serious pests of live stock and their habits are discussed in Chapter XXX. The stable-fly has also been considered as a possible agent in the transmission of pellegra.

Certain little moth-like flies, *Phlebotomus pappataci*, which on account of their habits are sometimes called "sand-flies," carry an unknown germ that causes a very infectious disease known as three-day fever, or sand-fly fever. But as this and several other diseases of lesser importance spread by insects do not occur in our country we need not discuss them.

The relation of ticks to several important diseases has already been discussed in Chapters XIX and XXVIII.

CHAPTER XXX

OTHER INSECTS AFFECTING MAN AND DOMESTIC ANIMALS

Besides the mosquitoes, house-flies and fleas, there are several other insects that affect man and his domestic animals more or less seriously. The habits of some of these make it quite possible for them to carry infection from one host to another under favorable conditions. So aside from the annoyance and suffering they may cause they must always be regarded as potential sources of greater danger.

Flies.—Among such troublesome and dangerous insects various kinds of flies are perhaps most important. The little "punkies," or "no-see-ums," *Ceratopogon* spp., that often occur in great swarms in certain regions, bite very severely and are extremely annoying to man and beast. The black-flies, or buffalo-gnats, *Simulium* spp., also fly in great swarms and inflict very painful bites. The lancet-shaped stylets of the

FIG. 172.—A black-fly, *Simulium* sp. (About 6 times natural size.)

FIG. 173.—Horse-fly, *Tabanus punctifer*. (A little larger than natural size.)

mouth-parts make a wound into which is injected poison from the salivary glands. Animals are driven frantic by the attacks of these pests and may even suffer death unless they are afforded some protection. Considerable losses are occasioned each year because of farmers not being able to work animals in the fields during the season that these insects are flying. The possible relation of these flies to pellagra has been referred to in the preceding chapter.

The larvæ of the black-flies are aquatic, attaching themselves to the surface of rocks in swiftly moving streams. It is difficult to fight them there, but some small streams may be cleared of their breeding places, or the water may be treated

FIG. 174.—Screw-worm fly, *Chrysomyia macellaria*. (Three times natural size.)

with phinotis oil and many of the larvæ destroyed without injuring the fish in the stream. Dense smudges will keep the adults away, and some protection may be afforded animals by smearing them with cotton-seed oil or oil and tar.

The horse-flies, gad-flies, breeze-flies and deer-flies, all belonging to the family *Tabanidæ*, can pierce through the toughest skin and are often a source of great annoyance to live stock. Some of them often attack man also. Cattle and horses sprayed with some crude oil emulsion are not attacked as freely as unsprayed animals. Laurel oil has recently been recommended as a fly repellent.

Horn-flies, *Hæmatobia serrata*, and the stable-fly, *Stomoxys calcitrans*, are among the most serious pests of cattle. Means for controlling the latter have been suggested in the previous

chapter, but it is harder to control the horn-fly because it breeds in the cow manure all over the pasture. Various repellent washes are recommended for use, but none is wholly satisfactory.

The screw-worm flies, *Chrysomyia macellaria*, often cause great suffering on account of the habits of the larvæ. These gray-flies, as they are sometimes called, may lay a mass of three or four hundred eggs on the surface of wounds on cattle, horses, etc. The larvæ which hatch from these eggs in a few hours make their way into the wound and feed on the surrounding tissue. Slight scratches that might otherwise quickly heal

FIG. 175.—Blow-fly, *Calliphora vomitoria*. (Two and one-half times natural size.)

often become serious sores on account of the presence of these larvæ. Many cases are on record of these flies laying their eggs in the ears or nose of children or of persons sleeping out of doors during the day. The larvæ, burrowing in the mucous membrane, cause terrible suffering and often death.

The blow-flies, *Calliphora vomitoria*, the blue-bottle flies, *Lucilia* spp., and the flesh-flies, *Sarcophaga* spp., all have habits somewhat like those of the screw-worm flies. The flesh-fly, instead of laying eggs, deposits living larvæ upon meat wherever it is accessible, and as these larvæ grow with

astonishing rapidity they are able to consume large quantities of flesh in a remarkably short time. In this way they may be of some importance as scavengers.

The bot-flies, family *Oestridæ*, are another group of flies that are a great source of annoyance, and often loss, to the stockman. Rarely, too, the larvæ of some of them may infest man. The adult flies look much like small hairy bumble-bees. The mouth-parts are rudimentary so they cannot bite, yet many animals have an instinctive fear of them and will do everything that they can to get away from the pests. The common bot-fly of the horse, *Gastrophilus equi*, attaches its eggs to the

FIG. 176.—Horse bot-fly, *Gastrophilus equi*. (Two and one-half times natural size.)

hair of the legs or some other part of the body of the animal. The horse licks off the eggs into its mouth. The eggs hatch just before or after they are licked off and the larvæ develop in the alimentary canal of their host. Sometimes the walls of the stomach may be almost covered with the larvæ that have attached themselves there. This of course seriously interferes with the function of this organ. When full grown, the larvæ pass from the horse with the droppings, and complete their transformations in the ground. There are two other species of bot-flies attacking the horses. These have habits similar, in most respects, to the species just described.

It is believed that the bot-flies of cattle, or the ox-warbles, *Hypoderma lineata*, and *H. bovis*, gain an entrance into the alimentary canal in the same way, that is by being licked from the

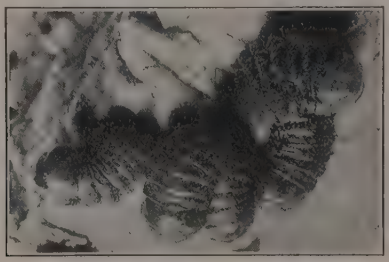

FIG. 177.—Bots, larvæ of *Gastrophilus equi*, in stomach of horse. (Enlarged.)

hairs on the body where the eggs have been laid by the adult fly. But instead of passing on into the stomach they penetrate

FIG. 178.—Ox warble-fly, *Hypoderma lineata*. (About two and one-half times natural size.)

the walls of the esophagus and later make their way through the tissues of the body, until at last they reach a place along the back just under the skin. Here, while completing their

development, they make more or less serious sores. When fully mature their larvæ drop to the ground and undergo their transformation to pupæ and finally to flies. Some entomologists believe, however, that the eggs are laid on the backs of the cattle and that the larvæ bore through the skin to the place where they are to complete their larval development. Although this is one of the most common pests of cattle this question in regard to its life-history has never been definitely settled. The sheep bot-flies, *Oestrus ovis*, lay their eggs in the nostrils of sheep. The larvæ pass up into the frontal sinuses, where they feed on the mucus and tissues, causing great suffering and loss. Many

FIG. 179.—Bot, larva of *Hypoderma lineata*, from cow. (Enlarged.)

other species of animals are infested by their own particular species of bots. Several instances are recorded where the ox-warbles have occurred in man, always causing much suffering and sometimes death.

Horses and cattle that can rest in the shade during the hottest part of the day are not bothered as much by bot-flies as are animals that do not have such protection. Cattle often obtain further protection by standing in the water when it is available. Horses that are thoroughly groomed and kept free from the eggs of the bot-flies will not, of course, be infested with the larvæ. After they have gained an entrance little can be done to cause the larvæ to leave the alimentary canal of the host until they are fully developed. The ox-warbles

are much more serious pests, but fortunately they can be controlled by concerted action on the part of all of the stock owners in a community. After the larvæ have attained considerable size they are easily detected as they lie under the skin on the backs of the cattle. When they are nearly ready to issue they can easily be squeezed out and destroyed. They

FIG. 180.—Body-louse, *Pediculus vestimenti*. (About eighteen times natural size.)

may also be killed while still under the skin, but bad sores are apt to result if this is done so it is much better to squeeze them out. If all of the cattle owners in a community attend to this early each spring, it is evident that the number of bot-flies will soon be so reduced that they will cause little trouble.

Lice.—There are two distinct groups of wingless parasitic insects commonly called lice. One group, the blood-sucking lice, belongs to the family *Pediculidæ*, order *Hemiptera*; the other, the biting lice, constitutes an independent small order, the

Mallophaga. The *Pediculidæ* are confined to mammals, the three species found on man and a few that infest domestic animals being the best known. The mouth parts are fused to form a flexible sucking tube, and the feet are provided with a single strong curved claw which enables them to cling to the hair of their host. The head-louse, *Pediculus capitis*, is very annoying on account of the intense itching caused by the bite. The eggs, called "nits," are attached to hairs, and are very hard

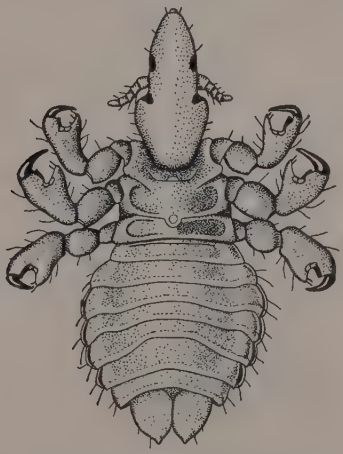

FIG. 181.—The sucking louse of the horse, *Hæmatopinus asini*. (About twenty times natural size.)

to remove. These lice are never common where cleanliness is the rule, but under certain conditions they may be met with. Thorough combing and washing followed by an application of pomade, vaseline or some such greasy substance will get rid of the pest. The body lice, *P. vestimenti*, known as "graybacks," "crumbs," "seam-squirrels," live on the body and hide among the clothing. They sometimes become very serious pests where the surroundings are not sanitary, but can be controlled by

cleanliness. Infested clothes that may contain some of the eggs should be boiled or steamed, or the inside of the seams smeared with mercurial ointment. The crab-louse, *Pthirius inguinalis*, lives on the hairs on protected parts of the body. Sulphur and mercurial ointment are the remedies used.

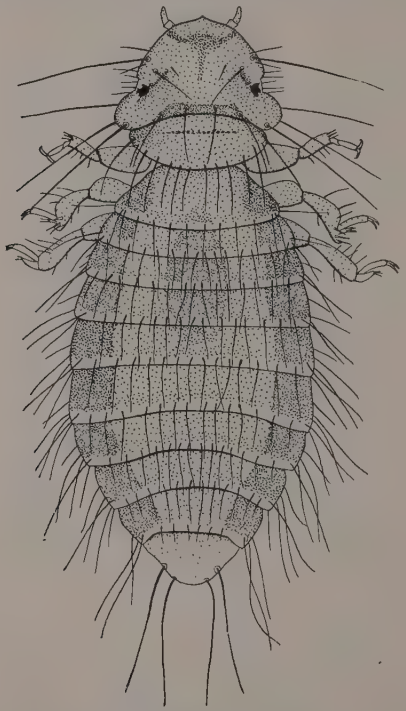

FIG. 182.—A chicken-louse, *Menopon pallidum*. (Greatly enlarged.)

Most of the sucking lice on domestic animals belong to the genus *Hæmatopinus*. Dogs, horses, cattle, sheep, hogs and other animals are infested with species peculiar to themselves. The animals may be freed from these pests by washing

thoroughly with tobacco water, or dilute carbolic acid, or dilute kerosene emulsion. Ointments made of kerosene and lard, or sulphur one part and lard four parts, are effective. It is possible to fumigate an animal by inclosing all but the head in a sack or tent and burning sulphur or tobacco inside the tent.

The *Mallophaga* do not suck blood, but feed on bits of dry feathers or hair which they bite off with their small sharp jaws. They are commonly called bird-lice, because most of them infest birds, but some species are found on mammals where they feed on the hair or epidermal scales. The injury done to the host is due chiefly to the irritation caused by the insects wandering over the body. They sometimes occur in such numbers as seriously to affect barnyard fowls. The common chicken-louse, *Menopon pallidum*, is about one-twentieth of an inch long and is an unusually swift and active little pest. The affected fowls make an effort to rid themselves of the pest by bathing in fine dust. Good dust baths should always be available for this purpose, and the roosts should be kept clean. Badly infected poultry houses should be sprayed with kerosene or fumigated by burning sulphur in them, and then thoroughly whitewashed.

Dogs, horses or other domestic animals infected with biting lice may be treated as recommended for sucking lice.

Bedbugs—Although bedbugs, *Acanthia lectularia*, usually occur only in neglected houses, they may be accidentally introduced into the cleanest places, and they are often met with in hotels. They cannot fly, as they have no wings, but they are active crawlers and may migrate from house to house when food becomes scarce. They are more commonly distributed on clothing, especially bed clothing and upholstered furniture. When crushed they give off a very disagreeable odor which is due to the secretions from glands at the base of the abdomen. They are nocturnal in their habits, hiding away in cracks in bedsteads or other furniture or in the walls during the day. Their very flat soft bodies are capable of being squeezed into seemingly impossible places. The mouth-parts are fitted for piercing and sucking blood. Normally they feed only on blood,

but they may possibly subsist for a time on moisture in wood or dust.

The bite is very irritating to most people, but no poison is secreted. The recurrent fever of Europe is probably transmitted by bedbugs, and it is quite possible that other diseases also may be carried by this unclean pest. Recent experiments have indicated that it may prove to be one of the agents in the spread of the bacillus that causes leprosy.

FIG. 183.—Bedbug, *Acanthia lectularia*. (About six times natural size.)

The simplest way to get rid of bedbugs is to clean all the furniture and woodwork thoroughly. Carpets and rugs should be removed, and every crack and crevice in furniture, picture frames, walls and floors should be given a liberal treatment with gasoline. Corrosive sublimate (bichloride of mercury) in water or alcohol may be used for the same purpose, but it is more expensive than gasoline and more apt to injure some articles. As the water or alcohol evaporates a thin coating of the powder is left that gives a large measure of protection as long as it lasts. Fumigation with hydrocyanic gas is more satisfactory, but this gas should be used only by some experienced

person who is well aware of the danger attending its use.

Bedbugs are sometimes found in poultry houses where they may be very annoying. The closely related bugs often found so abundantly in swallows' nests and in other places out of doors do not become household pests.

Cockroaches.—Like the bedbugs, the cockroaches are night foragers. But they are much less particular about the kind of food that they eat. Their mouth-parts are fitted for biting. Kitchens, pantries, restaurants, hotels and bakeshops where the air is warm and humid, are their favorite haunts, and almost any kind of organic matter that can be found around such places suits their taste.

FIG. 184.—The croton-bug, or German cockroach, *Ectobia germanica*. (Twice natural size.)

There are four common species found in dwellings in this country, only one of which is native. The American roach, *Periplaneta americana*, is the largest of these. It is light brown in color and about one and one-half inches long. The Australian roach, *P. australasia*, is nearly as large as the preceding species, but is darker in color. The Asiatic roach, *P. orientalis*, or black beetle, as it is sometimes called, is about one inch long, and brownish black in color. The wings of the female are rudimentary, and in the male the wings do not reach to the tip of the abdomen. The most abundant and destructive of the group in many parts of the United States is the little, yellowish-brown, German cockroach, *Ectobia germanica*, which is only about half an inch long. It is often called croton-bug because of its intimate association with the pipes of New York City's Croton water system.

The eggs of cockroaches are laid in small, purse-like, horny, brown cases which are usually carried about by the female until the young are ready to issue. It probably takes about a year for the young to become fully developed.

Although the actual damage done by these insects is not often very great, they are, on account of their unpleasant odor and their habit of crawling into everything, most disgusting creatures to have about the house. It is suspected that they may be concerned in the transmission of certain diseases by contaminating food. Fumigation with hydrocyanic gas is the best remedy to use when this is practicable. There are many roach powders on the market, but few of them are wholly satisfactory. Indeed it is usually only by a combination of several methods of fighting, such as poisoning, trapping and sealing up their hiding places, that one can hope to control the roaches in a badly infested house, unless fumigation is resorted to. All the cracks and crevices where the roaches hide should be filled if possible; when this cannot be done such places should be thoroughly syringed with a solution of bichloride of mercury. Sweet chocolate or sugar and powdered borax thoroughly ground together make a very good poison. It is most readily eaten from pieces of slightly moistened bread. Phosphorous paste makes a good poison when spread on moist bread. Many roaches may be trapped by placing food or some other attractive article in the bottom of a deep vessel and arranging sticks or papers so the insects can easily crawl from the floor to the edge of the vessel. The sides of the vessel should be steep enough so the roaches cannot crawl out after they have entered it.

Ants.—In the southern states a few of the common ants may become of some importance in the field or garden on account of their habit of making large bare areas around their nests or because they strip the foliage from plants. The introduced Argentine ants, *Iridomyrmex humilis*, are the worst of these, as they do considerable damage to citrus and other trees by destroying the opening blossoms or the very young fruit. In badly infested regions almost all kinds of flowers are attacked. All kinds of stored food products may be infested by these ants and the loss in store rooms from this source is often important. But it is as household pests that ants are of primary interest. One little red species, *Monomorium pharaonis*, makes its home in houses, building nests

between the walls, under the hearthstones, or in other suitable places. The small black ant, *M. minimum*, the pavement-ant, *Tetramorium cæspitum*, of many eastern cities, and other species which have their nests out of doors, frequently invade houses and cause great annoyance by getting into all kinds of food. As in the field so in the houses the Argentine ant is by far the most important in regions where it occurs. Indeed in places where this introduced species is well established the other species disappear, for the intruder attacks and finally overcomes, by sheer force of numbers, all other kinds of ants.

Nearly all ants live in large colonies in a common nest, but the Argentine ants build small nests or burrows anywhere throughout the infested region. Not only are the Argentine ants more numerous than other species, but they are more persistent in their search for food, and methods that usually afford protection from other ants are of little or no avail against this introduced marauder.

FIG. 185.—Argentine ant, *Iridomyrmex humilis*. (Much enlarged.)

The best way to get rid of most ants is to find the nest and treat it with carbon bisulphide, pouring a few ounces of the liquid in holes made in the nest and immediately stopping up the holes so the gas will be forced throughout the nest. Colonies of the house ants may often be treated with gasoline or boiling water. Dilute carbolic acid injected into the crevices through which the ants enter a room will sometimes drive them away. Oil of lemon diluted with alcohol will serve the same purpose for some species. When it is impossible to destroy the nests, many of the ants may be trapped by putting out scraps of attractive food or sponges wet with sweet syrup. The persistent use of such traps will usually give relief from the pests if the baits are removed as soon as they are covered with the ants. Powdered borax spread around the threshold or other places where the ants enter will act as a repellent. Wood or cloth that has been treated with a

saturated solution of corrosive sublimate will repel the ants as long as the poison remains. "Ant tape" is made by soaking ordinary cotton tape in a saturated solution of corrosive sublimate. After the tape is dry it may be fastened around table legs, on the edges of shelves or in other places. The ants will not cross the tape as long as the poison remains on it. It may thus afford protection for several months if kept dry. As corrosive sublimate is very poisonous it must not be used where children can reach it, and care must be taken to wash the hands thoroughly after handling it. It has been found that the most successful way to control the Argentine ant is to place a number of sponges that have been soaked in a weak solution of arsenic in convenient places about the yard or in the houses. A gallon of this poison may be prepared by mixing one-third of an ounce of arsenite of soda in a syrup that has been made by dissolving six pounds of sugar in a gallon of water. This poison acts very slowly and is carried to the nest by the workers and fed to the queen and the young so that the whole colony may be exterminated or driven away in a few weeks. The same remedy may prove effective in fighting other species.

FIG. 186. -The clothes-moth, *Tinea pellionella;* larva, larva in case, and adult. (Twice natural size; after Howard and Marlatt.)

Clothes-moths.—There are two common species of small moths whose larvæ attack woolen fabrics, furs and feathers. The case-making clothes-moth, *Tinea pellionella*, is very common, particularly in the North. The wings expand about half an inch, the forewings are grayish yellow with indistinct fuscous spots, and the hind wings are grayish. The eggs are laid on or near the articles upon which the larvæ are to feed. As soon as they hatch the larvæ begin to construct little cases or covers out of bits of the material on which they are feeding. This case is enlarged from time to time as the insect grows. There may be two or more generations in warm places.

The webbing, or southern clothes-moth, *Tineola biselliella*, is more abundant in southern latitudes. It is about the same size as the preceding species, and the fore wings are uniformly pale ochreous without any markings. The larvæ feed on almost any kind of dry animal tissue, but are especially destructive to woolens, furs, feathers and hair. They construct no case, but spin a cobwebby path wherever they go and when ready to pupate make silken cocoons.

Clothing in continuous use or carpets or hangings that are frequently aired and dusted, are not troubled by these insects. The woolen clothes, furs, etc., that are stored away for the summer, and carpets or upholstered furniture that do not receive regular and thorough cleanings suffer most. If woolens and furs are well dusted and allowed to hang in the sun for a few hours, and are then packed in tight paper boxes or wrapped carefully in linen they will not be bothered by the moths. Carpets are apt to become infested along the edges or under heavy furniture that is seldom moved. A liberal use of gasoline over the infested areas will kill the larvæ that are feeding there. Napthaline flakes or "moth balls" act as repellants for the moths, but do not kill the larvæ. The insects do not breed in temperatures lower than 40° F., and valuable goods are often placed in cold storage when it is necessary to pack them away for some time.

FIG. 187. Carpet-beetle, or "buffalo-moth," *Anthrenus scrophulariæ*, larva and adult. (After Howard and Marlatt; much enlarged.)

Carpet-beetles.—The carpet-beetles, *Anthrenus scrophulariæ*, or "buffalo-moths," as the larvæ are sometimes called, feed on carpets and sometimes on other woolen goods that are packed away. The adults are small, broadly oval, black beetles that are covered with minute black and grayish scales which give the insect a mottled appearance. The larvæ have habits somewhat like those of the clothes moth larvæ, and may be controlled by the same treatment.

Some of the insects that attack flour, meal and other grain

products are discussed in Chapter XXXVI. Absolute cleanliness will usually keep the kitchen and pantry free from these pests. No open, partially-used packages should be left for breeding places for these insects.

CHAPTER XXXI

CONTROLLING INSECT PESTS

The next nine chapters will be devoted to a consideration of the very important relations that the insects bear to our material welfare, in their capacity as pests of our crops, orchards and forests. It is estimated that the annual money loss occasioned by insects in the United States is approximately as follows:

Cereals	$300,000,000
Hay and forage	66,500,000
Cotton	85,000,000
Tobacco	10,000,000
Truck crops	60,000,000
Sugars	9,500,000
Fruits	60,000,000
Farm forests	11,000,000
Miscellaneous crops	10,000,000
Animal products	300,000,000
Natural forests and forest products	100,000,000
Products in storage	200,000,000
	$1,212,000,000

This summary takes into account only those insects which directly affect our crops or other products. We might well add to this something of the financial loss caused by those insects already discussed, that affect man himself, but this is a much more difficult problem. It has been estimated, for instance, that we pay more than $10,000,000 a year for screens for our houses to protect us from mosquitoes and flies, and yet this affords us only a small measure of protection. Such an amount is comparatively insignficant when compared to the reduced value in real estate because of the mosquitoes that infest many regions making them almost uninhabitable, or to the

tremendous financial loss resulting from the quarantine and suspension of business which, until recent years, always followed an outbreak of yellow fever in any region.

Again we might consider the great loss of time and energy that is occasioned by malaria in many regions. A man's producing capacity may be reduced 50 to 75 per cent. for a number of years because of this disease. This, of course, most seriously retards the development of the malarial regions, regions that might otherwise be producing millions of dollars where they now produce only hundreds of thousands. It is not conceivable that we can make any estimate in dollars and cents of the great bodily and mental suffering entailed as a result of some of the diseases that are carried by insects and of the hundreds of thousands of deaths that occur annually from these diseases. Yet these are by far the most important factors to be considered in estimating the economic importance of insects, and the work that is being done along the line of controlling the insects that carry disease germs is the work that most demands the co-operation and support of every citizen.

In no country in the world are the forces that are fighting insect pests so well organized as they are in the United States. The federal government maintains a large and very effective Bureau of Entomology employing more than one hundred men most of whom devote their whole time to the study of the insect pests and methods of controlling them. Nearly all states have their State Entomologists, who may or may not be connected with the state agricultural colleges and experiment stations, and many other horticultural officers and inspectors who devote a large part of their time to the study and control of insects.

We cannot fight insects successfully without some knowledge of their structure and habits and life-history. More than this, we must know something of their relation to other insects and other animals. So the study of economic entomology includes attention to systematic and morphologic and ecologic entomology. It is a much more comprehensive study than it is perhaps popularly supposed to be.

Government entomologists really devote a large part of

their time to the study of the general biology of insects, and many of their bulletins and special reports are scientific papers of much value to naturalists, as well as to the general public, for whom they are primarily issued. Directions for obtaining these bulletins and reports are given on page 419.

Sometimes the fight against an insect pest can be carried on successfully by one man in his own orchard or field, but more often the whole community must co-operate if lasting benefits are to be secured, because most of the insects so readily pass from one place to another. The necessity for such co-operation is well illustrated in the fight against flies and mosquitoes. One unclean stable, where the manure is left for a breeding place for flies, may be a source of annoyance and danger to all the homes in the community. For a successful campaign against house-flies, *all* the members of the community must see to it that there are no manure piles, open privy vaults, open garbage cans or other places where the flies may breed and feed, while a united effort should be made to trap and kill as many of the adult flies as possible. Some mosquitoes, such as the yellow-fever mosquito and others, breed only near houses and fly but a short distance. In such instances a single person may free his house from these pests by seeing that the mosquitoes find no breeding places near. But many kinds of mosquitoes fly for considerable distances, and the problem of their control then becomes one for the community as a whole to deal with.

Natural Enemies of Insects

Insects have many natural enemies which in many ways help to control the injurious species. Indeed, were it not for this condition many of them would increase so rapidly that they would be wholly beyond the control of man. It is a significant fact that with all our improved methods for fighting insects the total amount of damage that they do to our crops is increasing rather than decreasing. This is due in part to the introduction of new pests, and in part to the more extensive and intensive cultivation of crops. But the fact that we are changing the natural conditions of vast areas and often destroying many of

the natural enemies of some of the insects, and thus upsetting the balance that had been established in nature, is accountable for a large measure of this increase.

The part that birds play in the control of the insect pests of forest, orchard, garden and field is of much more importance than is usually realized. Many species of birds feed chiefly upon insects. From an examination of the stomach contents

FIG. 188.—Phœbe, a well known flycatcher, 90 per cent. of whose food consists of insects.

of large numbers of birds it has been estimated that insects form about 96 per cent. of the food of flycatchers in some regions, 95 per cent. of the food of wrens, 94 per cent. of warblers, 65 per cent. of woodpeckers and meadow-larks, and more than 25 per cent. of the native sparrows. Swifts, swallows, titmice, crows, jays, blackbirds and many others feed largely on insects. As many as 3000 to 5000 insects have been taken from the stomach of a single bird. Of course many beneficial insects are eaten with the injurious ones, and some of the birds also take toll of fruit in the orchard or grain in the field but with

the notable exception of the introduced English sparrow and of the few species of native sap-suckers, and two kinds of hawks, practically all of our birds are to be regarded as friends and helpers on the farm or in the orchard.

The common garden toads eat many insects and worms during the evenings while they are feeding. Spiders trap and destroy many of the smaller insects and are especially serviceable on small flowering bushes and garden plants.

But it is to the insects themselves that we must look for some of the most destructive enemies of others of their class. It will be convenient in considering these to divide them into two groups; first the *predaceous insects*, which run or fly about attacking and devouring other insect species, and, second, the *parasitic insects*, which spend a part or all of their lives in or on the body of their hosts.

FIG. 189.—A ladybird-beetle, *Coccinella californica;* larva, pupæ, and adult on Lawson's cypress. (Twice natural size.)

Among the predaceous insects the ladybird-beetles are perhaps the most important, as in both the adult and larval stages they destroy great numbers of plant-lice, scale-insects and other noxious insects. A remarkable example of the good that they may do is furnished by the Australian la[dy]beetle, *Novius cardinalis*, that was introduced in[to] to aid in controlling the cottony-cushion sca[le], a pest that threatened the destruction [of] dustry in California. So rapidly d[id] and so effectively did they do thei[r] soon under control and is no longe[r] Many other species of ladybird-b[eetles] into this country, but none has b[een] this one.

Many of our native species [are] ticularly destructive to certain ki[nds]

In California millions of living ladybird-beetles are gathered each winter, while hibernating in great masses in the high Sierras, and as soon as the aphids begin to appear in destructive numbers in the melon fields and other places large shipments of the beetles are sent to the infested regions.

The larvæ of the lace-winged-flies and the syrphus-flies are also great enemies of aphis and other soft-bodied insects. The predaceous ground-beetles (family *Carabidæ*) and the tiger-beetles (family *Cincindelidæ*) destroy many larvæ and

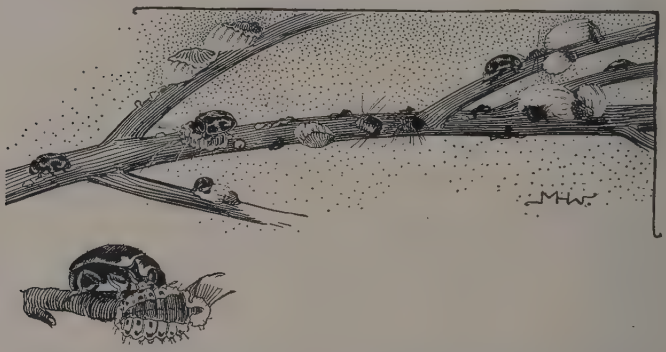

FIG. 190.—The fluted scale, *Icerya purchasi*, attacked by the Australian ladybird-beetle, *Novius cardinalis*. In the lower left-hand corner, a *Novius* which has just issued from its pupal case. (Upper figure slightly enlarged; lower figure much enlarged.)

that can be captured on the ground. The ily *Reduviidæ*) are all predaceous, as are f *Hemiptera*. We have already called tance of dragon-flies in controlling

asects the tachina-flies (family ies of various kinds of caterpillars. he body of the insect into which soon as they are hatched. Here roying the host until it pupates. china-flies are laid on the leaves,

and leaf-feeding larvæ take the eggs into their alimentary canal where they hatch. The parasites then bore their way into the

FIG. 191.—A predaceous ground-beetle, *Calosoma sycophanta*. (Natural size.)

FIG. 192.—A tachina-fly, *Blepharipeza adusta*, the larva of which is an internal parasite. (About twice natural size.)

body tissues of the host. The parasitic *Hymenoptera*, which include some of the best known and most important of the parasites and which comprise hundreds of different kinds,

FIG. 193.—Braconid cocoons on a caterpillar that has been killed by the parasites. (About natural size.)

each attacking its own particular single or few host kinds, have been discussed in Chapter XVII.

The most extensive experiment in attempting to control a serious insect pest by its insect enemies is the work that is now

FIG. 194. FIG. 195.

FIG. 194. –Aphids on a leaf, which have been parasitized by a Braconid parasite. (About natural size.)

FIG. 195.—Larvæ and pupæ of the oak tree moth, *Phryganidia californica*, that have been killed by a disease caused by bacteria. (Natural size.)

being carried on by the Bureau of Entomology in the fight against the gipsy-moth in the New England states. The way

in which this insect was introduced and the damage that it does is referred to on page 507. Trained entomologists have been sent to every foreign land where the gipsy-moth is known to occur, and they have gathered and sent to this country all of the different insect enemies of the pest that they could discover. Some of these have proved to be of no effect in our country, others aid a little, and still others give promise of being important factors in the control of the moth. Those in charge of the work do not expect to be able to find any one insect that will do for the gipsy-moth what the Australian ladybird-beetle did for the cottony-cushion scale, but they do expect that if they introduce a great many parasitic and predaceous kinds enough of them may work together to check the slow spread of the pest and finally control it.

Insects are often attacked by fungi and by certain bacterial diseases. Sometimes these are very important factors in controlling outbreaks of chinch-bugs, scale-insects, grasshoppers, various larvæ and other insects. But the conditions which favor the development of the fungi or bacteria are often beyond our control, and usually there is but little that we can do to aid in the spread of these diseases.

Preventive Methods of Control

The natural enemies of insects do much, indeed, toward controlling their numbers, but some of the worst pests require the constant attention of the farmer or orchardist or he soon sees his crops badly injured or totally destroyed. We can never hope to get rid entirely of some of the pests, but by careful management they may be kept in check so that they may not reap the lion's share of the harvest. The most important thing in dealing with insects is to *begin early*. Too often when a pest makes its appearance the orchardist waits for a more convenient season to commence fighting it. Meantime the insect has had a chance to lay its eggs or, perhaps, to produce several generations thus increasing many fold the number that must now be fought. Until one understands how very rapidly many insects multiply one can hardly realize the importance of trying to get rid of a pest just as soon as it is found in the

orchard or field. It is usually much easier and cheaper to prevent an insect from getting a start in the orchard or garden than it is to fight it after it has gained a firm foothold. "An ounce of prevention is worth a pound of cure."

Among the most effective means of preventing insect injury may be mentioned the following:

High Cultivation.—This not only makes the tree or other plant yield its best returns but it is a well known fact that a strong healthy plant is not nearly as apt to be attacked by as many insect pests as one that is already weakened or, if it is attacked, it is able to stand much more injury without the effect being shown in the crop it yields. The first and best way of fighting insect pests is then to keep the plant in the very best condition possible by high cultivation, judicious pruning, fertilizing, etc.

Clean Culture.—Many of the most injurious insects pass the winter months under rubbish of various kinds that lies scattered over the farm. If this rubbish is not allowed to accumulate such insects will be more likely to perish during the winter. Keeping clean will also reduce the opportunities for feeding and breeding and allow a more thorough application of insecticides. In orchards this recommendation for clean culture is of especial importance. Many insects breed and complete their development in dead wood or fallen fruit, others pass the winter months or lay their winter eggs upon the smaller branches of the trees. If the orchardist would take the pains to trim out and *burn* all the dead and infected branches, and to see that all fallen fruit was destroyed, there would be little complaint of some of the insects that are now serious pests.

Crop Rotation.—Many insects live only on one kind of plant, and when not able to find this plant they perish or are scattered so as to do little damage. This fact may often be taken advantage of by a system of crop rotation.

Protection of Plants.—Many small plants, especially in the garden, may be protected by screens or other devices for keeping the pests away from the plants.

Late Plowing.—Many insects may be killed or exposed to their enemies by plowing the field late in the fall. Some of

the wire-worms and the eggs of grasshoppers and other pests are thus destroyed. Late plowing of fallow lands is especially important, as there are usually many insects in such fields.

Trap Crops.—It is sometimes profitable to plant a crop that is attractive to the insects that are to be combated and after the insects have gathered there, to destroy the whole crop by burning or plowing it under or spraying it with some insecticide that will kill the insects. In this way the main planting of the same or other crops may be left comparatively free from the pests.

Active Methods of Control

In spite of all our care and precautionary measures, however, many pests will certainly become established in the orchard or garden or field, and then the fight must be waged against the insects themselves.

Hand-picking.—This is often the simplest way of getting rid of many of the larger insect pests. Large caterpillars, like the tomato-worm and the larvæ of other moths, are easily seen and destroyed. Tent-caterpillars are also best fought by gathering them after they have collected in their "tents" and crushing or burning them. In the fall or winter the eggs of such moths as the tussuck-moth are easily gathered and destroyed.

Trapping, etc.—Insects may often be found collected in considerable numbers under loose boards or boxes scattered over the field. If such places be examined occasionally many injurious insects can be destroyed. The larvæ of certain moths, as the codling-moth, pupate in any sheltered place they find on the trunk of the tree. Advantage may be taken of this habit by placing a band of burlap around the tree. Under this the larvæ collect and they may easily be destroyed. The use of lights in the field to attract moths is more or less successful in some places. Numbers of cut-worm moths may thus be destroyed. Codling-moths are not attracted to these lights.

Insecticides.—The most widely used and perhaps the most effective method of fighting insect pests after they have obtained a foothold in the orchard, is the use of *insecticides*, or insect

poisons. These may be considered under four heads: first, the *internal poisons*, or those which take effect by being eaten along with the ordinary food of the insect; second, the *contact insecticides* that kill the insects when applied directly to their body; third, the *gases* that are used for fumigation, and, fourth, various substances that act as *repellents*. The kind of insecticide to be used depends in a large degree upon the structure of the mouth-parts of the insects. For beetles, the larvæ of moths and butterflies, and others with biting mouth-parts the internal poisons are used, while for the various insects with sucking mouth-parts, as the plant-lice, scale-insects, etc., the contact insecticides are used. The reason for this is very plain. It would be useless to spray a plant with poison when it was infested by an insect with sucking mouth-parts, for such insects obtain their food from the juices of the plant which are not reached at all by the poison. But if the plant is infested by biting insects, such an application of poison to all the leaves and tender shoots would be effective, for with each bitten off and swallowed mouthful of leaf, the insect would get a dose of the poison.

Internal Poisons.—*Paris green* was for a long time regarded as the most efficient of the internal poisons and is still used to a limited extent.

The poison is applied as a spray, using one pound of Paris green to 150 to 200 gallons of water for such trees as apples, pears, etc. For peach and plum trees and other plants with delicate foliage which is very susceptible to the poison the mixture should not be stronger than one pouud of Paris green to 250 or 300 gallons of water. A pailful or two of fresh lime water should be added to every 200 gallons of the mixture to prevent the poison from scalding the foliage. In preparing the mixture the Paris green should first be mixed into a fine paste with a small amount of water; it should then be strained thoroughly and the bulk of water added. The lime may be added to the paste before straining, in amount equal to the amount of poison used, instead of being added to the mixture as above recommended. The mixture must be kept well stirred during the spraying.

For fighting such insects as cut-worms and grasshoppers a bran mash poisoned with Paris green is often very effective. This may be made as follows: thoroughly mix one pound of Paris green with twenty-five pounds of bran or middlings and moisten with about a gallon of water which has been sweetened by adding one or two quarts of cheap molasses. This will make a stiff mash that may be placed in the affected field, a tablespoonful or so in a place.

For most purposes *arsenate of lead* is now used instead of Paris green. It is less injurious to the foliage, remains in suspension longer, and in many other ways is better than Paris green. It may be manufactured at home, but it is usually safer to buy some of the reliable brands that are on the market. It comes in two forms, as paste and powder. Four to ten pounds of the paste, or two to five pounds of the powder, are used with every 100 gallons of water. The spraying should be so thoroughly done that all the foliage and fruit is covered with a thin film of the poison. Some fungicide, such as Bordeaux mixture or sulphur-lime, is often used in connection with this insecticide, and the trees are thus freed from their insect pests and fungus diseases with one spraying. A gallon of molasses or twenty-five pounds of glucose is often added to every 100 gallons of the spray when arsenate of lead is used for flea-beetles and other leaf-feeding insects on cabbages, turnips, etc.

White hellebore is often used instead of arsenic, especially in the garden. It may be applied dry, diluted with five or ten parts of flour, or it may be used as a spray, one ounce to a gallon of water.

Contact Insecticides.—Of the many contact insecticides used, the *sulphur-lime solution* is, in many respects, the best. It acts quickly on the scaly covering of such insects as the San Jose scale and soon kills the insect. It has the additional advantage of being an excellent fungicide as well as an insecticide. There are many brands of concentrated sulphur-lime solution on the market, and most orchardists now prefer to buy some of these rather than prepare the mixture themselves. In using these all that is necessary is to add water and apply thoroughly with the spray pump. The strength of the

various commercial brands varies somewhat but as a rule nine to twelve gallons of the concentrated solution to 100 gallons of water should be used in treating trees in the winter for such insects as San Jose scale and blister-mites. For use in the summer for fungus and soft-bodied insects, such as aphids and young scale-insects, the proportion should be about two or three gallons of the concentrated solution to 100 gallons of water. It has recently been demonstrated that in some instances sulphur-lime solution may take the place of arsenical sprays as it acts as a stomach poison as well as a contact insecticide. Sulphur-lime, three gallons to 100 gallons of water, has been used with some success in controlling the codling moth. The addition of a little arsenate of lead will probably be found advisable.

It is somewhat difficult to prepare sulphur-lime wash with uniformity unless one is well prepared for this work. The best plan is to obtain one of the bulletins issued by the state in which the orchardist lives, and follow carefully the directions given there. The following formula is one that is often used:

Unslaked lime	5 pounds
Flowers of sulphur	11 pounds
Water	5 gallons

Put a little of the water in a kettle or boiler over a good fire; add the lime and after it has started to slake sift the sulphur over it adding enough water to maintain a thin paste. After the slaking and mixing are completed add more water and boil for about one hour adding enough water from time to time to make up for evaporation. If properly made the mixture will be of an amber color, and there will be but little sediment. This is a concentrated solution which, before using, should be diluted to the strength indicated above.

Kerosene emulsions or *distillate oil emulsions* are often used for many of the soft-bodied sucking insects. The following is the standard formula for kerosene emulsion: kerosene 2 gallons; soap (preferably whale-oil soap) 1/2 pound; water 1 gallon. The soap should be dissolved in the water heated to boiling and the kerosene then added. Churn or otherwise

thoroughly mix the kerosene and soapsuds until a thick emulsion is formed which will set on cooling. When needed mix one part of this emulsion with twelve parts of water and spray over the insects.

The *distillate-oil emulsion* can only be made satisfactorily with a power sprayer. The proportions are: distillate oil 20 gallons, fish oil or whale-oil soap 30 pounds, hot water 12 gallons. Five and one-half gallons of the emulsion should be used to each 100 gallons of water when spraying for such insects as thrips. About a pint of strong tobacco extract added to each 200 gallons of diluted distillate oil emulsion adds much to its efficiency as a spray for thrips.

There are several *miscible oils* on the market under various trade names. These are convenient to use because they readily mix with water. The proportions to use for the winter and summer sprayings are generally indicated on the package containing the oils.

Resin sprays are still used in some regions, particularly for white-flies on citrus trees. The following formula has proved satisfactory: resin 20 pounds, caustic soda, pulverized, 7 pounds, fish oil 3 1/2 pints. Boil together in a little water and finally add enough water to make 100 gallons.

A *carbolic acid emulsion*, made by adding 1 gallon of crude carbolic acid to eight pounds of whale-oil soap that has been dissolved by boiling in eight gallons of water, makes a good stock solution for sprays for aphis, mealy-bugs and other soft-bodied insects. For use add twenty gallons of water to every gallon of the emulsion.

Whale-oil soap or common laundry soap are often used for spraying for aphids or other soft-bodied insects.

Tobacco extracts and *nicotine solutions* are sometimes very efficient when used by themselves or in connection with some other material.

There are several mixtures that are used for dipping animals infected with ticks or mites. Sulphur-lime, crude oil, white arsenic, tobacco and other substances are used for this purpose. As the use of most of these is attended with more or less danger unless properly done the detailed directions given in some of

the recent government and experiment station bulletins should be consulted. (See p. 419).

Pyrethrum, Persian insect powder, or *buhach,* is a powder made by pulverizing the flowers of pyrethrum. It gives off a volatile oil which is poisonous to insects but does not affect the higher animals. It is used principally as a household remedy, where it can be dusted on or near the insects.

Gases.—As the citrus trees and some others have a very dense foliage and retain their leaves the year round it is difficult to spray them with the ordinary insecticides. When it is necessary to treat them for insect pests they are usually fumigated with *hydrocyanic acid gas,* which is generated under a tent that is placed over the tree. Nine ounces of water are placed in an earthenware vessel and three ounces of sulphuric acid added; then three ounces of potassium cyanide are dropped into the liquid and the tent quickly closed as the gas that is immediately generated is deadly to all animal life. The amount of gas necessary to kill all the insects on the tree varies with the species of insects and the size of the tree. Careful tables are given in government and state bulletins relating to this subject.

Nursery trees that are infested with scale-insects or other pests may be placed in a tight bin or a fumigating house and given a thorough treatment with this gas. It is also sometimes used in greenhouses for scale-insects, aphids, etc., and in mills that have become infested with the Mediterranean flour moth or other pests. This gas is sometimes used to kill household pests such as bedbugs, cockroaches, etc., but as it is very dangerous it should never be used except by some experienced person.

Carbon bisulphide is used in killing insects in stored grain and sometimes also in treating subterranean insects. It is bought and used as a liquid which volatilizes into a heavy, ill-smelling gas which is not quite as deadly as hydrocyanic gas but is so strong that large doses prove fatal to all animal life. It can be used in closets infested by clothes-moths by exposing some of the liquid in a saucer on the floor, (better on a shelf as the fumes are heavier than air and sink rather than rise) and

closing the door and cracks of the closet. Or infested clothing may be put into a tight trunk or box together with a small saucer of the liquid. *It is highly explosive and must never be used in the presence of any artificial light.*

When sulphur is burned, very poisonous fumes, mostly *sulphur dioxide*, are given off. This gas is fatal to all animal life and is sometimes used in fumigating rooms or other enclosed spaces that are infested with insects. Under the head of "Clayton gas" it has recently been much used for fumigating ships and ship's cargoes to kill the rats and insects that are so often found in the holds. It is very penetrating and effective but is usually objectionable on account of its strong bleaching properties especially in the presence of moisture. Seeds treated with this gas will not germinate.

Repellents.—There is a popular belief that any ill-smelling substance will keep insects away from plants. While this is not wholly true there are some substances which when applied to a plant seem to afford it more or less immunity from the attacks of certain insects. Bordeaux mixture, crude carbolic acid and thick soap washes are among the most effective of such substances and the various proprietary repellant mixtures that are on the market usually depend on one or more of these substances for their usefulness. As a general rule but little reliance can be placed on them.

How to Obtain State and Government Publications

Frequent reference has been made and will be made in the following chapters to various reports or bulletins issued by state officials or by the United States Department of Agriculture. Some of these are technical in character and intended for special students but most of them are written for the general public and give in a clear concise manner the results of the latest studies and investigations on the subjects discussed.

The reports and bulletins of the various State Agricultural Experiment Stations can be had by applying to the director of the station in whatever city this station is situated. When making application for such bulletins the applicant should state

the particular subjects in which he is interested, and any available publications on that subject will be forwarded to him. In a few states the State Entomologist is not an officer of the Experiment Station. In such instances applications for his publications should be directed to the State Entomologist. His office is usually in the capital city. Some states maintain a State Board of Horticulture or Agriculture which issues reports or bulletins that are often of great interest.

Most of the government bulletins are also for free distribution. Each month the office of Experiment Stations issues a list of the publications that have been published during the preceding month. This "Monthly List of Publications" is sent regularly to all who apply for it. Address the Editor and Chief of the Division of Publications, U. S. Department of Agriculture, Washington, D. C. Only a limited number of each issue of many of the government publications is available for free distribution. When this supply is exhausted the publication may be had by applying to the Superintendent of Documents, Washington, D. C. A small charge, usually only five to twenty cents for bulletins, is made by this office. On request the Superintendent of Documents will mail a price-list of all the government publications relating to entomology, ornithology, agriculture or any other subject.

The Division of Publications has recently issued a very helpful circular (No. 19) giving a list of the "Publications of the United States Department of Agriculture Classified for the Use of Teachers." This may be had by applying to the Editor and Chief of the Division.

The Department of Agriculture also issues a series of "Farmers' Bulletins" and a "Year Book," both of which contain a great deal of interesting and useful information on many topics relating to agriculture.

The Farmers' Bulletins may be had by applying to the Secretary of Agriculture. The Year Books can usually be more readily obtained by applying to the congressman representing the district in which the applicant lives. The congressman may also supply the Farmers' Bulletins.

CHAPTER XXXII

INSECTS INJURIOUS TO ORCHARD TREES

It is estimated by careful and expert observers that insect pests take, each year, about one-fifth of the American fruit crop. This is an annual money loss to the growers, and to the nation, of about sixty million dollars. A large part of this loss can be prevented.

The orchard pests include insects of many kinds, representing different orders, and varying greatly in life history, habits and structure. The injury to the trees may be to the roots, the trunk, the leaves, the flower buds, or the fruit. Apple trees, for example, have their roots attacked by the woolly-aphis, their trunks mined by the round-headed and flat-headed borers, their leaves eaten by tent-caterpillars, the buds attacked by the larvæ of the bud-moth, and the fruit burrowed into by the codling-moth grub.

The insects attacking a particular part of the tree, as the leaves, may effect their injury in different ways. They may eat the leaves, as caterpillars, beetles and other insects with biting mouth-parts do; or suck the plant juices from them, as the aphids, scale-insects and other insects with sucking mouth-parts do. Similarly with the fruits. Some insect pests bite holes in them, some suck juice from them, and some bore unsightly tunnels in them, the insects feeding and developing in the very heart of the fruit.

Even in the case of two different insects that attack the same parts of the same kind of orchard trees in much the same way, as with two biting insects that eat the leaves, there may yet be such differences in their life history and habits that the best remedies for them may be radically different. The remedy for one, which may be a wingless insect, might be an easy means of preventing its access to the leaves; for the other, a winged

kind, which cannot be kept from the leaves, the remedy may be the application of a poison on the leaf surfaces so that with each bite will go a dose of poison.

Thus there is not much practical advantage in discussing in general terms the insect pests, or the conditions of insect attack, of orchard trees. We believe it will be better worth while for the elementary student to try to get acquainted with a few of the more important specific orchard pests in his locality, and to that end we have given in the following paragraphs, brief accounts descriptive of the insect, its life, the character of the injury done by it, and the approved remedies for it, of a number of the most serious and widespread of these pests. Some of these insects can be found and observed by the student at almost any time of the year in almost any orchard.

For fuller information about the insects mentioned in this chapter, and for accounts of many others, injurious to orchards, some manual of economic entomology may be consulted. Sanderson's "Insect Pests of Farm, Garden and Orchard" is an excellent recent book of this kind. O'Kane's "Injurious Insects" is another.

Codling-moth (*Cydia pomonella*).—Of all the pests of apples, the codling-moth is easily first in importance. In many orchards where the codling-moth is uncontrolled by spraying 50 per cent. to 90 per cent. or more of the fruit is infested. By proper spraying the amount of loss may be reduced to only 5 per cent. or even 2 per cent, yet this insect now costs us, when we consider both the loss from bad fruit and the amount expended in fighting it, about twenty million dollars a year.

The winter is passed in the larval stage as a little white grub safely hidden away in a tough little cocoon underneath the rough bark of the tree or in other protected places in the orchard or in the store room where the apples have been stored for the winter. Early in the spring the larva changes to pupa, and about the time the trees are in bloom there issues the small purplish-brown moth. It has a wing expanse of but three-fourths of an inch. The fore-wings are marked by fine

greenish lines or bands and often by minute golden spots on the outer margin. The hind wings are grayish, and darker toward the outer margin. The codling-moths fly at dusk and usually lay their eggs on the leaves. The larvæ may feed on the tender leaves for a short time, but they soon make their way to the calyx, or blossom, end of the forming fruit and enter there. A few may enter at the stem end or in the sides of the fruit. For the next three or four weeks they burrow and feed in the apple, usually around the core, and, finally, having attained their full growth, bore their way out and drop

FIG. 196.—Codling-moth, *Cydia pomonella*. (Twice natural size.)

to the ground and hide themselves under pieces of rough bark or other rubbish where they form a thin cocoon. In some regions there is only a single generation each year, but in most regions there are two and in some places three and even part of a fourth.

If all the larvæ that hide themselves away in the fall were to live through the winter the insect would be a much more serious pest than it is. Fortunately a large proportion of them is destroyed by the birds during the winter. Many apples are carried into the store houses before the worms have issued from them, and when these leave the apples they hide away in protected places, and the moths that issue the next spring will fly back to the orchards unless the store rooms are carefully screened so that they cannot escape. In many places

it has been found worth while to tie bands of burlap around the tree so that the larvæ will find there suitable places to pupate. During the summer these bands are examined often

FIG. 197.—The larva, or worm, of codling-moth, *Cydia pomonella*. (Three times natural size; after Slingerland.)

and any larvæ or pupæ found are destroyed. In the fall they should be removed or very carefully examined to see that none of the larvæ pass the winter in them.

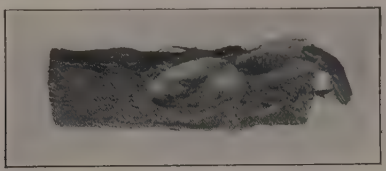

FIG. 198.—Cocoons of codling-moth larvæ under bark on old apple tree. An empty pupa case shows where the moth has issued from one of the cocoons. (Natural size.)

Spraying with Paris green or arsenate of lead must be relied upon as the principal means for controlling this pest. Three

or four pounds of arsenate of lead (paste) to one hundred gallons of water make the most effective spray. The proper time to spray for this pest is just after the petals fall and while the calyx cup is still open. It is of prime importance that the calyx cup of every small apple or pear be filled in order that the first meal that the young larva takes on the fruit will contain enough of the poison to destroy it. In regions where most of the larvæ of the first brood hatch at about the same time it has been found that a single spraying thoroughly done at the proper time will save 95 or sometimes 98 per cent. of the fruit. In places where the larvæ issue irregularly it may be desirable to give a second spraying about three or four weeks after the blossoms fall, or even a third still later. The first spraying should be done by using a coarse spray with a pressure of from 150 to 250 pounds. This drives the spray through the stamens and into the lower calyx cavity. Later sprayings may be applied as a finer mist in order that a thin film of the poison may be left over the surface of the fruit and leaves.

The Apple-maggot, or Railroad-worm (*Rhagoletis pomonella*). —Sometimes an apple that is apparently perfectly sound externally will be found to be "railroaded" inside by a dozen or more little maggots that make discolored streaks throughout it. When these larvæ leave the apples they pupate in the ground or in the boxes or barrels where the apples have been stored, and early the next summer the adult flies issue. They are a little smaller than the house-fly, and have the wings conspicuously marked by four black connected bands; the body is blackish with yellowish head and legs, and with narrow white stripes across the abdomen.

This pest can be controlled by destroying infested summer apples by gathering them up at least twice a week, or by allowing hogs to run in the orchard and eat all the apples that fall.

The Cherry Fruit-fly (*Rhagoletis cingulata*).—This insect, the larvæ of which are often found in cherries, looks very much like the adult of the apple-maggot, but it is somewhat smaller and the black bands across the wings are arranged differently.

All fruit found to be affected should be destroyed before the larvæ have a chance to escape and pupate.

The Mediterranean Fruit-fly (*Ceratitis capitata*).—This is probably the most important fruit pest in the world. At the time this is being written it does not yet occur in North America, but there is always danger of its being introduced from Hawaii or other tropical islands where it is now doing much damage. Under favorable conditions it multiplies very rapidly and as it attacks many kinds of cultivated and wild fruits its introduction into this country might result disastrously to much of our fruit, particularly on the Pacific Coast and in the

FIG. 199.—Mediterranean fruit-fly, *Ceratitis capitata*. (Much enlarged.)

South. The fly is a little smaller than the common house-fly and is closely related to the two fruit-flies just described. Figure 199 shows the characteristic markings of the wings. The quarantine officers in all of our ports are carefully watching for this pest, and are destroying all fruit or vegetables that may contain the living larvæ.

The Plum Curculio (*Conotrachelus nenuphar*).—While this little insect causes most injury to plums it may also attack peaches and cherries. The adult is a thick-set beetle a little more than three-eighths of an inch long, black, but covered with short, fine, brownish hairs; there are also a few patches of white hairs. The back is marked with conspicuous ridges

and tubercles. The head is produced into a long snout. The female beetle hibernates under leaves or rubbish, and as soon as the fruit is formed commences to lay her eggs in it in small holes that she makes with her snout. After laying her eggs she makes a small crescent-shaped cut in the skin of the fruit. This characteristic mark has suggested the common name "little Turk" for this pest. The larvæ usually feed around the pit, often causing the fruit to drop. When full grown they crawl out, pupate in the ground, and the adult beetles, which issue three or four weeks later, feed on the ripening fruit, often doing much damage before they seek out a suitable hiding place in which to pass the winter.

FIG. 200.—The plum curculio, *Conotrachelus nenuphar*. (Enlarged; after Slingerland.)

As the beetles have the habit of "playing possum" when alarmed many of them may be caught by jarring the tree with a padded club and causing them to drop to a canvas that has been spread under the tree. Some fruit growers use curculio catchers made by stretching a canvas on a frame that is mounted on wheels, a slit being left in one side to allow the apparatus to be wheeled against the trunk of the tree. Recent experiments seem to indicate that spraying the leaves with arsenate of lead may be a satisfactory method of control as the beetles feed for awhile on the foliage when they first issue in the spring.

Tent-caterpillars (*Malacosoma americana*).—The larvæ of many moths often occur in such numbers in the orchard that they quite strip the trees of their foliage. Among the most conspicuous of this group of pests are the tent-caterpillars, so-called on account of their habit of living together in colonies and spinning a large web or tent in which or on which they rest at night or at other times when not feeding. When full grown each finds a convenient place to spin a thin, tough, white cocoon from which, a few weeks later, the adult moth issues and lays the eggs which are to remain on the trees over winter. The eggs are laid in a mass usually on the smaller branches,

often making a complete band around a twig. They are covered with a frothy, glue-like substance which protects them during the winter and furnishes the first meals for the young larvæ.

These pests have many natural enemies, such as birds, Hymenopterous parasites and an important bacterial disease. These help much to control them, but it is sometimes necessary

FIG. 201.—Egg mass and small tent of tent-caterpillar. (About two-thirds natural size.)

to resort to active methods of control. The eggs may be pruned off in the winter and placed in a box covered with a screen so that the parasites may be allowed to escape and the larvæ be retained when they hatch. The tents containing the young larvæ can be quickly gathered and destroyed when they are small. Spraying very early, before the blossoms appear, with arsenate of lead will kill many of the larvæ.

Canker-worms.—The canker-worms, inch-worms, measuring-worms, or loopers are common throughout nearly all parts

of the United States. There are two species, the spring canker-worm, *Paleacrita vernata*, which has only one pair of abdominal

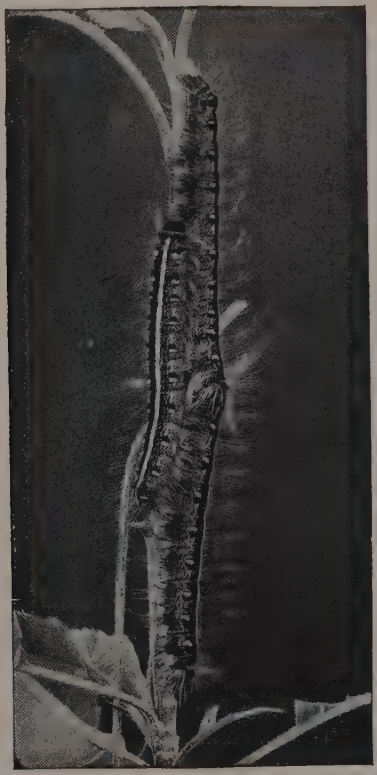

FIG. 202.—A trio of apple tent-caterpillars, larvæ of the moth *Malacosoma americana*. These caterpillars make the large unsightly webs or tents in the apple trees, a colony of the caterpillars living in each tent. (Natural size; after Slingerland.)

legs, and the fall canker-worm, *Alsophila pometaria*, which has two pairs. Otherwise they are very similar in appearance.

They have similar habits also, except that the adult of the spring canker-worm lays her eggs early in the spring, while the moth of the fall canker-worm lays hers late in the fall. The larvæ of both species issue about the same time in the spring and feed on the tender foliage. The young canker-worms have a habit of dropping from the tree when it is jarred or shaken and hanging suspended by a slender thread which they

FIG. 203.—California tussock-moth, *Hemerocampa vetusta;* larva and cocoon with an egg mass on the cocoon. (About natural size.)

spin from the mouth as they drop. They pupate in the ground and the spring canker-worm passes the winter in this stage, the adult issuing early in the spring. The female moth is entirely wingless and less than one-half of an inch long. They climb up the trunks of the trees and lay their eggs in irregular masses underneath the loose bark or in cracks or crevices. The

fall canker-worm moths issue during November and December and lay the eggs which are to hatch early the next spring.

The most efficient remedy is to spray with arsenate of lead as soon as the foliage is well open. A second later spraying is sometimes desirable. It is a common practice to place bands around the trees to prevent the females crawling up to lay their eggs. These bands usually consist of a strip of some heavy paper tied tightly around the tree after the bark has been made smooth. It is then covered with some sticky substance, such as "tanglefoot," which will prevent the moths from crawling over it.

The White-marked Tussock-moth (*Hemerocampa leucostigma*).—The females of the tussock-moths are similar in

FIG. 204.—California tussock-moth, *Hemerocampa vetusta;* male above; wingless female below. (Natural size.)

appearance to the female canker-worm moths, being entirely without wings. When they issue from the cocoon they seldom travel far, often simply crawling on top of the cocoon to deposit their eggs. The larvæ vary a great deal in color and markings, but they are always covered with long blackish or yellowish hairs and have conspicuous tufts toward the anterior and posterior ends of the body. On the Pacific Coast the most common tussock-moth is *H. vetusta*, but there are other species that may be found in the orchard or in woodland trees.

The best method of control is to gather the eggs during the winter and destroy them. The larvæ seem to be very resistant to poisons, and when the arsenical sprays are used it is necessary to make them very strong.

Climbing Cut-worms.—Several species of smooth-bodied cut-worms often climb the trees, eating the foliage or destroying the young fruit. Sometimes these cut-worms go in great

FIG. 205.—Green-fruit worms, *Xylina grotei*, at left, and *Xylina antennata*, at right. (Natural size; after Slingerland.)

bands or armies traveling across the country and destroying all the vegetation in their path. The adults, which are moths that usually fly only at night, are mostly grayish or brownish, and are often called owlet-moths on account of the peculiar appearance of the eyes and head.

About the only successful method of combating cut-worms after they have once gained foothold on the trees is to jar them off and destroy them. Fortunately they are attacked by several natural enemies which generally keep them in control.

The Bud-moth (*Tmetocera ocellana*).—Often the unfolding leaves of fruit trees are tied together with silken webs making

an irregular nest in which the larvæ of the bud-moth feed and in which they pupate. Because they attack the buds before they are open they are able to do considerable damage before anything can be done to control them.

A careful spraying with arsenate of lead just as the leaves begin to unfold is about the only remedy that can be recommended.

The Pear Thrips (*Euthrips pyri*).—For several years this little insect has been the most serious pest with which the orchardists of central California have had to contend, and recently it has been discovered that it also occurs in some of the eastern states where it does considerable damage. It attacks many kinds of orchard trees, but does particular injury to pears, cherries and prunes. The adult thrips are minute, black-bodied insects with their four long narrow wings fringed with long hairs. They appear early in the spring and soon make their way into the tenderest part of the bud, often completely destroying it. A little later they begin laying the eggs from which the wingless young thrips hatch. These continue the destructive work begun by the adults. The insect passes the winter in the larval and pupal stages in the ground, the adult issuing very early the following spring.

FIG. 206.—The pear thrips, adult. (Much enlarged; after Moulton.)

In fighting this pest some insecticide must be used that will penetrate the buds and kill the thrips without injuring the buds. The distillate oil emulsion and tobacco extract (see page 417) have proved most efficient in California. The first spraying must be done as soon as the adult thrips are numerous on the trees, the second application should follow ten days later, and still a third, which is for the larvæ, should be given about two weeks after the second. Deep plowing in the fall

and winter will destroy many of the larvæ and pupæ that are in the ground.

The Pear-leaf Blister-mite (*Eriophyes pyri*).—This little mite, that causes red blister-like blotches on the leaves of the pears and sometimes of the apples, is not an insect, as is commonly supposed, but is an Arachnid and is discussed on page 213.

The Peach Borer (*Sanninoidea exitiosa*).—This insect is probably the most important of those that attack the trunk of orchard trees. Not only the peach but the apricot, plum,

FIG. 207.—California peach-tree borer, larva of *Sanninoidea opalescens*, in cocoon. (About natural size.)

prune and nectarine may be seriously affected by it. The eggs are laid on the outer bark near the base of the trunk. The larvæ burrow in and feed on the inner bark usually close to the surface of the ground. Their presence is indicated by gummy exudations mixed with the castings of the larvæ. Several larvæ feeding on a tree may completely girdle it or so weaken it that it will bear little fruit and be much more subject to the attacks of other insects or diseases. Much of the sawdust-like castings and bits of bark are incorporated in the cocoon which the larva spins in the end of the burrow or on the surface of the tree, or in the ground close to the surface. The adult

insects are beautiful, clear-winged, steel-blue moths. The abdomen of the female is marked by a conspicuous orange band, that of the male by three or four much narrower stripes.

The moths may sometimes be kept from laying their eggs on the tree if the trunk is wrapped with some heavy paper and the earth mounded up around the crown. Various repellent or protective washes have been tried with but little success. After the larvæ have entered the tree they must be dug out and destroyed. If the trees are well mounded up

FIG. 208.—Adults, male and female, California peach-tree borer, *Sanninoidea opalescens*. (About natural size.)

early in the spring it will greatly facilitate the work of "worming" early in the fall, for most of the young larvæ will be above the surface of the ground when the mounds are levelled.

A closely related species known as the California peach-tree borer, *S. opalescens*, occurring on the Pacific Coast, has habits and a life history similar to the eastern species and yields to the same methods of control.

The Peach Twig-borer (*Anarsia lineatella*).—Early in the spring many of the tender shoots on the peach trees will often

wither and die. If these are examined, minute, brownish, black-headed larvæ may be found in them. These larvæ bore down the center of the stem for one or two inches. When the firmer wood is reached they leave the dead shoot and attack another live one; thus one larva may destroy several twigs. When full grown the larvæ crawl down the branches to the trunk of the tree, where they pupate. The small dark gray moths that issue from these pupæ lay their eggs on the new twigs near the bases of the leaves. These eggs soon produce the second generation of larvæ which feed on the twigs as did the first generation. In some places a third brood of larvæ may appear late in the fall. These, as well as the members of the second brood, will often attack the fruit, usually working in or around the seed, often doing much damage and always making the fruit unattractive.

The larvæ of the last brood pupate early in the fall, and the moths that issue from these pupæ lay their eggs close to the crotches of the tree. The young larvæ that issue from these eggs bore into the bark in the crotches and make a little cell in which they pass the winter. Little turrets made of pellets woven together with silk spun by the larvæ mark the locations of these silk-lined cells in which the larvæ hibernate. As soon as the buds begin to grow in the spring the larvæ leave their burrows and begin their destructive work. The most effective remedy is to spray the trees with sulphur-lime as soon as the buds begin to swell. This will kill the larvæ after they have opened up the winter cells and are migrating from these to the tender shoots.

The Round-headed Apple-tree Borer (*Saperda candida*).—Frequently the trees in young apple orchards are injured by cylindrical round-headed larvæ boring in the trunk. A few of these larvæ working in a small tree may entirely girdle it. After feeding in the cambium for two seasons the larvæ bore into the heart of the wood, and not until the third season do they change to the pupæ from which the adult beetles issue.

The methods of control are much the same as those suggested for the peach borer, the object being to keep the beetle from laying her eggs on the tree, and to cut out any larvæ that may

have gained an entrance before they have had time to do much injury. A heavy coating of whitewash kept over the trunk of the trees during the summer affords much protection.

There is also a flat-headed borer that works in the trees in much the same way, and can be controlled by the same methods.

The Periodical Cicada (*Cicada septemdecim*).—It is commonly supposed that cicadas do much damage to the orchard trees. As a matter of fact, however, the injury that they cause is not particularly serious except to young trees. When the female is laying her eggs she makes rather large holes or wounds in the bark with her ovipositor. As soon as the young hatch they drop to the ground and bury themselves in the soil where they feed on roots and other substances for more than sixteen years, finally changing to the pupæ or nymphs. Then, seventeen years after the eggs have been laid, they issue as the adult cicadas, which soon lay their eggs and die. As there may be more than one brood in a locality with different times of emergence it is not always seventeen years between the outbreaks. Government bulletins giving dates upon which all the various broods occurring in the United States may be expected to issue, can be obtained by making application as suggested on page 420.

There are other species of cicadas that complete their development in much less time. Although these insects do not at all resemble grasshoppers, the two have been confused under the term locust, the periodical cicada often being referred to as the seventeen-year locust; the term locust, however, is properly applied only to the grasshoppers.

Aphids, or Plant-lice

In structure and habits the plant-lice (family *Aphididæ*) are among the most interesting of our insects. They are all very small and soft-bodied, and feed upon the leaves or stems of plants, sucking the sap by means of a long slender beak. Their life history is subject to considerable variation among the different species, but they all agree in certain features.

The eggs are usually laid in the fall on the twigs or other parts of the plant on which the insect is feeding. These eggs go over the winter. The young aphids that hatch from these eggs in the spring immediately begin feeding upon the host plant. Usually this is a generation of females. When about two weeks old they begin giving birth to living young which in turn give birth to other young and so through the summer. Thus there is a series of generations of wingless females that give birth parthenogenetically to living young. In the fall there appears a generation that is composed of both males and females which are usually winged. After mating, the females lay the winter eggs. At any time during the summer when food becomes scarce or when conditions are otherwise unfavorable, there may appear winged generations of females that fly to other plants and thus provide for the distribution of the species. This method of reproduction and distribution makes possible a very rapid increase of the number of individuals. The offspring from a single female, if all the members of the summer generations lived, would amount to hundreds of millions. Fortunately, they do not all live. They have many natural enemies, chief among which are the ladybird-beetles, the syrphus-fly larvæ, the lace-wing-fly larvæ, the braconid-flies, etc.

Certain secretions from the body of the aphids play an important part in their life. Through small pores or openings scattered over the body, many kinds, as the woolly aphis and others like it, secrete a waxy substance that forms a mat of felted or woolly threads which afford the insects considerable protection. Nearly all of the aphids also secrete a sweet, sticky substance known as honey-dew. Formerly it was supposed that this honey-dew came from the two little tubercles that occur on the posterior end of the body of many of them, but it is now known that it issues in drops from the alimentary canal. Sometimes so much is produced that the plants and the ground below are quite covered with the sticky, honey-like secretion. Many insects are very fond of this honey-dew, the ants being especially partial to it. On page 492 is given an account of a particular way in which the ants care for cer-

tain aphids for the sake of their honey-dew. But the ants do not always assume such a definite relation to the welfare of the aphids. Usually they appear on aphis-infested trees only to feed on the honey-dew, and neither injure nor care for the aphids. The black sooty fungus that grows on this honey-dew often completely covers the leaves and fruit making them very dirty and disagreeable to the sight and touch.

The Green Apple Aphis (*Aphis pomi.*)—This is one of the most common aphids found on apple trees. It feeds on the tender tips of the green shoots and upon the young leaves, causing the leaves to become twisted and curled in such a way that they afford excellent protection for the aphids that are feeding within. At any time during the summer winged females may appear and fly to other trees. Early in the fall the sexual generation appears and the females lay their eggs on the apple twigs. During the winter time these small, shining black, oval eggs may be found on the twigs, usually near the tips. The best method of control is to prune off and destroy all of the twigs on which the eggs are found. A strong sulphur-lime spray will kill many of the eggs, but it does not always give entire satisfaction. As the leaves begin to curl soon after the aphids attack them it is hard to reach them with any spray. A good strong tobacco spray, however, will kill many of them if it is used very early. Kerosene emulsion may also be used. It is necessary to use considerable force with any spray for these insects in order to drive it into the curled leaves.

The Rosy Apple Aphis (*Aphis sorbi*).—This species resembles the preceding in habits and general appearance, but the body is usually rosy in color. The color may vary, however, from grayish to purplish or black. The winter eggs are not as conspicuous as the eggs of the green aphis, and are not easily detected. It is necessary therefore to rely upon the efficiency of the sulphur-lime wash for destroying the winter eggs, or upon some of the contact sprays for killing the insects after they have attacked the leaves. It is thought that one generation of these aphids leaves the apple and migrates to some unknown food plant on which they may pass the principal part of the summer. In the fall some of the winged females return

to the apple trees and give rise to the sexual generation which produces the winter eggs.

The Woolly Apple Aphis (*Schizoneura lanigera*).—This is the most destructive of the apple aphids, doing particular damage in young orchards, and as its most injurious work is on the roots of the trees its presence is often not suspected until the trees have been badly damaged. These aphids secrete a white, woolly, waxen substance that covers the body, and when a number of them are feeding together the white

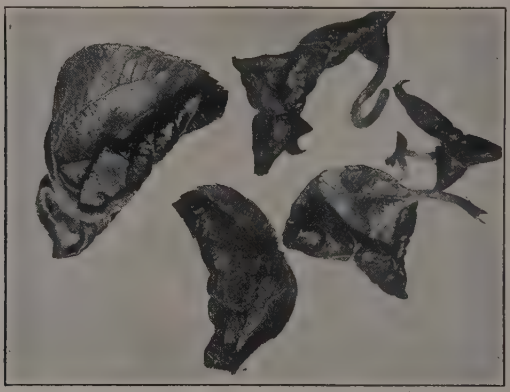

FIG. 209.—Apple leaves curled by rosy aphis, *Aphis sorbi*. (Reduced.)

patches that they make are quite conspicuous. The forms that feed above ground usually attack the new shoots or the tender bark about wounds or scars on the trees. The greatest damage, however, is done by the root-feeding forms. These gather in small colonies over the smaller roots, where their feeding causes knots or galls. If they are abundant many of the smaller rootlets are killed and young trees, particularly, are thus seriously injured. The larger roots may become very knotty and much deformed, but the aphids are usually found on the smaller tenderer roots. Many of the wingless aphids live over

the winter on the roots of the tree. Early in the spring some of these migrate to the trunks or branches, where they feed during the summer. There are several generations of apterous females during the summer. In the fall winged females appear which, it is believed by some students, migrate to elm trees, where the eggs are laid in crevices in the bark. These hatch early in the spring and cause the curly leaves on the elm. A little later a generation containing winged females

FIG. 210.—Woolly aphis, *Schizoneura lanigera*, and the galls caused by their attacks on apple tree roots. (Two-thirds natural size.)

appears, and some of these migrate back to apple trees and start new colonies there. Elm trees near an orchard may thus serve as a source of infection. It would probably be much easier to keep nursery trees free from woolly aphis if the nurseries were not located near groves of elms.

The aphids that occur on the trunk and branches may be killed by spraying with kerosene emulsion, whale oil soap, tobacco extract or other contact sprays. It is necessary that

the spray be applied with much force in order that it may penetrate the woolly secretion that covers the insects. The root forms are harder to control, as it is difficult to reach them. But if the earth is removed from all of the roots that are within eight or ten inches of the surface, and those affected then treated with kerosene emulsion or tobacco extract, most of the aphids may be destroyed. If the ground is thoroughly wet with the emulsion or tobacco it seems to act as a repellant and the roots may not be infested again for some time. As it is the young trees that suffer most from the attacks of this insect, great care should be taken to see that the pest is not introduced into the orchard with nursery stock. No nursery stock that shows any indication of having been attacked by this aphis should be accepted, for by no treatment can it be made absolutely safe. Nursery men often sprinkle tobacco dust on the ground along the rows of growing young trees. This not only kills some of the aphids that are close to the surface, but it acts as a repellant, for a while at least. Trees grown on Northern Spy stock do not seem to be as seriously attacked as those grown on other roots.

Black Peach Aphis (*Aphis persicæ-niger.*)—There are several other species of aphids that attack the peach, plum and other orchard trees, usually confining their attacks to the foliage or tender twigs. The black peach aphis is of particular importance because, like the woolly aphis of the apple, it attacks the roots as well as the leaves and branches. Both the winged and the wingless aphids may be found on the foliage during the summer, but winged forms do not seem to occur on the roots. The aphids may be found on any of the roots throughout the year, but they do most damage to the smaller roots. As they cling tenaciously to the roots they are very apt to be distributed on nursery stock, and great care should be taken to keep them from being introduced into the orchard in this way. The colonies are established on the foilage in the spring by some of the larvæ migrating from the roots. The methods suggested for controlling the woolly aphis should be used in fighting this species.

Scale-insects

Although most of the *Coccidæ*, or scale-insects, are so small or obscure that they are usually overlooked by the ordinary observer they are economically the most important group in all the insect class. The scale-insects attack almost all kinds of trees and shrubs, but it is difficult to make anything like a reasonably accurate estimate of the amount of damage done by them because so many factors are involved. Some trees may harbor many scale-insects and yet show but little injury, others when only slightly infested by certain species suffer severely. The injury may be only temporary, causing the leaves or fruit to drop, or it may be permanent, retarding, dwarfing or even killing the tree. In discussing the development and life history of the scale-insects it will be convenient to group them into three more or less well-defined groups. The first group includes the mealy-bugs, which are common in almost all greenhouses, and a few others, most of which move about over the plant freely until ready to lay their eggs. In these the segmentation of the body remains distinct, and the legs and antennæ are functional throughout the life of the female. The second group includes the genus *Lecanium* and others, such as the common black scale and the cottony maple-scale. The young insects of this group wander about freely for a while, but before they are half grown they insert their long projecting mouth-parts into the tissues of the plant and remain stationary for the rest of their life. The body-wall becomes dark and hard, often very convex or hemispherical, and usually all resemblance to an insect is lost. The third group includes those species that have the body concealed by a scaly covering made up of a waxy secretion in which is imbedded the molted skins of the insect. The San Jose scale, the oyster-shell scale, the rose-scale, and others, are examples of this group. With the second molt the female loses her eyes, antennæ and legs, and becomes a sac-like creature covered over with its protecting scale and with its long beak thrust into the plant tissue.

In the first, or mealy-bug, group, the eggs of many species issue from the body before they are hatched, the female often

secreting white filamentous or flocculent masses of wax which protect the eggs. In the other groups the eggs may be hatched within the body of the mother and the young produced alive, or they may be protected underneath her body, or under the waxy scale, until they hatch. The young, or larvæ, of all the species are very similar, being minute, mite-like, little creatures that move about freely for a while. It is in this stage that they scatter over the different parts of the tree and sometimes even to different trees or orchards. The females molt twice during their development. With some there is little change in the appearance of the insect after these molts, but with others, as we have seen, the changes may be very remarkable. During the first stage, and often during the second also, the males and females are very much alike, but in their further development the male makes one more molt than the female and enters a pupal stage in which the appendages of the future adult can be clearly seen folded against the sides of the body. The adult males that issue from these pupæ are remarkable in several respects. Although belonging to the order *Hemiptera*, the adults of which normally have two pairs of wings, the male Coccids have only one pair, the second pair being represented by two slender, little, hooked organs which hook over the hind margin of the wings. They have no mouth-parts or mouth-opening for taking food. In the place where the mouth-parts are usually situated there is an extra pair of eyes. In many species the end of the abdomen is provided with long, pointed, stylet-like processes.

As the females never acquire wings, and as the larvæ are so small that they can crawl for only a few yards at the most, it is evident that these insects must depend on some agencies besides their own powers of locomotion for their general dispersal. The active young larvæ may crawl on the feet of birds, or upon insects, such as the ladybird-beetles or the ants that are often found on trees that are infested with the scale-insects, and thus be carried for considerable distances to other trees or to near-by orchards. Or they may crawl on the ladders or boxes or other articles that are used in gathering the fruit. It is evident, however, that nursery stock or budding or grafting materials are the

chief agencies by which scale-insects are transferred over any great distances. The fact that most of them are very small and inconspicuous makes it an easy matter for them to escape detection, and thus important species are often introduced into new regions even when a close watch is being kept for them. For the same reason nursery stock and imported plants of various kinds are the principal means of transferring these pests from one country to another.

Besides the damage that the scale-insects do by sucking the juices from the plant, and, in some instances at least, poisoning the tissues on which they are feeding, they may secrete a considerable amount of honey-dew, which makes the leaves, branches and fruit sticky and disagreeable to handle, and furnishes a medium in which a black sooty fungus grows. Badly infested trees present a very disgusting appearance, and the fruit is often unfit for use until it is washed thoroughly to remove these substances. Many insects, particularly the ants, are very fond of this honey-dew and feed on it as they do on the honey-dew secreted by the aphids.

The list of scale-insects known to attack orchard trees is a long one, but we shall note only a few of the most important.

The San Jose Scale (*Aspidiotus perniciosus*).—The San Jose scale is probably the most important of all the scale-insects, as it has become distributed over the whole United States and is responsible for the death of many thousands of orchard trees and the loss of much fruit in orchards in which the trees are not killed but seriously weakened. This insect was probably introduced into America from China, and was first discovered on some trees in an orchard near San Jose, California. Thus it came to be popularly known as the San Jose scale.

The covering wax scale of this insect is so small and flat and so closely resembles the color of the bark, that it makes the insects very difficult to detect, especially when there are only a few on a tree. On the fruit or leaves or new branches their presence is more easily detected on account of the conspicuous red spot that usually surrounds them. When the tree is badly infested the scales often form a complete crust over the bark and branches, giving them a characteristic

grayish appearance. If a piece of the outer bark of the infested tree is cut away the cambium will be seen to be discolored by numerous red spots, which, in the case of a serious infestation, may coalesce, staining the whole outer surface of the cambium. The scale of the male is usually darker than that of the female, and oblong-oval instead of circular. The

FIG. 211.—San Jose scale, *Aspidiotus perniciosus*, on fruit, leaves, and stem of a pear tree. (Reduced.)

scales of the young of the male and female are alike, both being small circular and black. The insect passes the winter in the immature condition under these black scales on the trunk or the branches of the tree. In the early spring the females become mature and begin to produce living young. The young soon make their way from underneath the scale of the mother, and, after wandering about for a short time, settle down and

begin active feeding. Soon after this they begin the secretion of the waxy substance which is to form their scaly covering. Their development is very rapid and after about thirty days they themselves begin to produce living young. Thus there may occur from two to six generations during the summer.

There are several kinds of parasites that are of more or less importance in controlling the San Jose scale, but none of these acts quickly enough to make it unnecessary to use active measures in fighting the pest. Many kinds of sprays have been tried, but the sulphur-lime spray is the one which is now most generally used. The directions for making and using this spray will be found on page 416. Before spraying, the trees should be pruned back as much as is practicable so that all of the remaining wood may be thoroughly covered. In some regions miscible oils are extensively used.

There are four or five other species of scale-insects that look very much like the San Jose scale, and, indeed, can only be distinguished from it by the use of the lens, but as their habits are much the same and as the same remedies are to be used for them they need not be especially discussed.

Oyster-shell Scale (*Lepidosaphes ulmi*).—As the name indicates, the scale of this insect is shaped somewhat like an elongate oyster shell. It is long and narrow, usually somewhat curved toward the posterior end. The color varies from light brown to dark brown. This is a very common pest on almost all kinds of fruit trees, occurring also on many other trees both cultivated and wild. As it is large enough to be easily seen it is perhaps better known than almost any other species. It passes the winter in the egg stage, the eggs being well protected by the firm tough scale under which they lie. In many regions only a single brood occurs each year, but in the South there may be two broods. This insect is subject to the attack of several natural enemies, among the most important of which are the chalcid-flies, which sometimes control the pest fairly well. It is very difficult to kill the eggs by spraying in the winter, but if the trees are thoroughly sprayed with the sulphur-lime wash just before the buds open most of the young will be killed soon

after hatching. Kerosene emulsion or whale-oil soap or other sprays may be used just after the young hatch as they are very easily killed before they are protected by the scale.

The Scurfy-scale (*Chionaspis furfura*).—This scale is very common on apple and pear trees, but may also attack cherry, peach, plum and many other trees. The scale of the adult female is whitish or dirty gray, flat, and irregularly ovate. The yellow exuvium is at the narrowed anterior end. The scale of the male is snow white, and elongate with the sides nearly parallel. The males and the females usually occur on different branches. They pass the winter in the egg stage and so are controlled by the same methods as are recommended for the oyster-shell scale.

FIG. 212.—The European fruit Lecanium, *L. corni*, on twig of apricot tree. (Natural size)

The European Fruit Lecanium (*Lecanium corni*).—There are several species of scale-insects that belong to the group commonly known as Lecaniums, but as they are similar in appearance and habits only one species will be described. *L. corni* was formerly known under many different names as it varies somewhat in appearance under different conditions and on different host plants. In many regions it is usually known as the plum-scale. In the west it is commonly known as the brown apricot-scale. It is usually quite convex, sometimes almost hemispherical, but often oval or even pointed at one or both ends. The color varies from light brown to dark brown, a medium reddish-brown being perhaps the prevailing color. The surface is usually shiny and often marked by fuscous transverse or longitudinal markings and irregular pits. The young insects may be found on the twigs and branches of the tree during the winter time, as it passes the winter in the immature stage. Any large apparently full-grown scales which may be found during the winter are the remains of the dead

bodies of mothers that have laid their eggs early in the summer. A small chalcid-fly is a very common parasite of this scale and often controls it effectively when it once becomes well established in an orchard. The parasites cannot be depended on for absolute control, however, and spraying is usually necessary. The sulphur-lime spray gives very good results, but some prefer a kerosene emulsion, one part to four parts of water, or a 5 per cent. or 6 per cent. distillate oil emulsion. The spraying should be done in the winter in order that the over-wintering young may be killed.

CHAPTER XXXIII

INSECTS AFFECTING CITRUS FRUITS

Insect pests are among the most serious obstacles to the successful growing of citrus fruits. In spite of the fact that California growers spend more than half a million dollars annually in fighting the scale-insects (*Coccidæ*) in their orange and lemon groves, the losses caused by these pests are still enormous. It is estimated that the Florida orange growers would receive annually at least one-half million dollars more for their crop if the white-fly, *Aleyrodes citri*, could be exterminated in their groves.

As the attack on citrus trees is made chiefly by a few insects that are closely related to each other, and hence are much alike in the nature of their injurious feeding, and in their structure, life-history and general habits, the remedies for the citrus pests are less various than those used in the warfare against the insect enemies of the deciduous orchards. Hence certain generalizations can be made concerning insect attacks on citrus fruits and concerning the remedies for them.

The injuries are chiefly caused by sap-sucking insects of the order *Hemiptera*. These insects, though small, are prolific breeders, and when once allowed a foothold in a grove increase rapidly to enormous numbers. They suck the juices from leaves and fruits, causing the former to wilt and the latter to be rendered unmarketable. As most of the citrus insects secrete honey-dew, the sooty fungus, *Capnodium*, whose spores germinate freely in this substance, frequently grows in a close felted mass over the attacked leaves and fruits, not only rendering them unsightly and disagreeably dirty, but actually seriously hurting the tree by interfering with the functions of the leaves. The fungus closes the stomata, or breathing pores, in the leaves, and prevents the proper exchange of gases necessary to the tree's health.

The remedies for the insect pests must be such as will kill them by external contact, or by suffocating them. The spraying of arsenical poisons on the trees would have no effect, for the food is drawn by the insects from below the surface. Fumigation by hydrocyanic gas, the application of kerosene emulsions or similar contact poisons, and recourse to distributing and encouraging the natural insect enemies of the pests, are the remedies chiefly used.

The following paragraphs give brief accounts of the character and life of a number of the more important of the pests. They should enable those students who have opportunities to visit orange and lemon groves to become acquainted with the insects, and to understand the means of controlling them. Most of the citrus fruit pests, it will be noted, are scale-insects and, therefore, the general account of these insects given in Chapter XXXII should be referred to in connection with the accounts in this chapter of various species of the group.

The White-fly (*Aleyrodes citri*).—This is by far the most important pest of the citrus trees in the Gulf states. The adults are small white insects with two pairs of wings covered with a white waxy powder, which has suggested the popular names of "white-fly" or "mealy-wings." These insects prefer to rest in quiet shady places, hence they are less common in dry open groves than they are in groves where the foliage is dense and there is considerable moisture. The eggs are laid on the underside of the leaves, preferably on new leaves. The young larvæ are similar in appearance to young scale-insects, and move about freely for a short time before they settle on the underside of the leaves and begin feeding. As they are whitish-green in color and translucent they are hard to see. The pupal stage, which is entered a few weeks later, is similar in appearance to the later larval stages. There are usually three broods during the year. As the undersides of the leaves are often almost completely covered with these pests the injury that they may do by sucking the juices from the leaf tissues is often very great. Perhaps the greatest injury, however, is caused by the sooty mould that grows in the honey-dew that is secreted by these insects. This honey-dew drops on the

leaves and fruit, and the fungus growing in it forms a thin covering that seriously interferes with the function of the leaf and very materially damages the fruit.

Certain fungus diseases that attack the white-flies often control them quite effectually but it is sometimes necessary to resort to spraying. The resin wash has been much used. A spray made by thoroughly emulsifying two gallons of paraffine oil with one gallon of whale-oil soap and one gallon of water is strongly recommended. One gallon of the stock emulsion should be used in fifty gallons of water. December, January, and February are the best months to spray for these insects, as practically all of them are then in the larval stage. As it is very difficult to reach thoroughly all of the foliage on an orange or lemon tree with any spray mixture, it is much more satisfactory, where possible, to fumigate with hydrocyanic acid gas. If properly done at the season suggested for spraying, it will effectively control the white-fly.

There are two other species of white-fly, *A. nubifera*, and *A. howardi*, affecting citrus trees, but they are similar in appearance and habits to *A. citri*.

Black Scale (*Saissetia oleæ*).—This is perhaps the most important scale-insect on the orange trees of the Pacific Coast, not so much on account of the direct injury caused by the loss of sap, which the myriads of insects are constantly drawing from the leaves and branches, but because, like the white-fly, it secretes a great deal of honey-dew in which a sooty mould grows. This is an insect widely spread over the world and long known as a pest of olives and oleanders. The adult female is almost hemispherical in shape, a little longer than broad, hard or leathery in texture and dark brown or black in color. The younger stages are flatter and on the dorsal side are marked by one longitudinal and two transverse ridges, forming the letter "H." The adult also shows this H, but less plainly. The black scale is not nearly as serious a pest in the Gulf region as it is on the Pacific Coast.

In 1900 there was introduced into California a small Hymenopterous parasite, *Scutellista cyanea*, of the black scale that has proved to be, in some localities at least, an important factor

in its control. Sometimes as high as 80 per cent. of the scales will show the small hole whence the adult parasite has escaped from its host. Yet the numbers of living scales that are left are great enough often to make it necessary to use some artificial methods of control. Most growers rely on fumigation to control this pest, but in some cases, especially in the case of young trees, it is practical to spray. The kerosene sprays discussed on page 416, have been found most satisfactory.

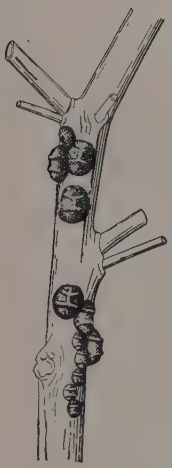

FIG. 213.—Black scale, *Saissetia oleæ*, on orange twig. (Slightly enlarged.)

FIG. 214.—Young of black scale, *Saissetia oleæ*. (About seventy times natural size; after Quayle, photo by Doane.)

The hemispherical scale, *S. hemisphærica*, looks very much like the black scale, but the dorsal surface is smooth and shining and does not have the ridges that form the letter H. It is often found on citrus trees out of doors, but is a more common pest in greenhouses, where it attacks many kinds of plants. The soft brown scale, *Coccus hesperidum*, is also sometimes

associated with the black scale, but is easily distinguished because of its reddish-brown or yellowish color and by minute darker spots or bars on its dorsal surface which may form more or less distinct radiating lines. It is elongate oval in shape. It is often very abundant on the trees, where it does considerable damage by taking sap from the plant. This species is attacked by three or four kinds of internal parasites that usually keep it well in control, so that the grower does not often have to resort to sprays or fumigation.

The Red Scale of California (*Chrysomphalus auranti.*) — This is one of the most destructive scale insects in California.

FIG. 215.—Red scale, *Chrysomphalus auranti*, on lemon leaf. (Enlarged; after Quayle, photo by Doane.)

Unlike the black scale it does not secrete the honey-dew in which the sooty mold grows, but the direct effect of the attack on the tree is much more serious. It attacks all parts of the tree, trunk, branches, twigs, leaves and fruit. The trees are often killed within two or three years after the first infestation if they are not properly cared for. Even when the insects

are not abundant enough to injure the tree seriously they may cause considerable loss by their presence on the fruit. Attention is usually called to the pest by the presence of small light yellowish spots on the leaves. The scale of the female is almost circular in outline, very flat, and about one-thirty-second to one-sixteenth of an inch in diameter. The scale of the male is more elongate. This insect increases in numbers so rapidly that although it is attacked by several natural enemies it is necessary to take active measures early to control it when it gains a foothold in the orchard. Fumigation is the most practical remedy.

The yellow scale, a variety of the red scale, is very similar in appearance and habits to the red scale, and is only distinguished from it by its lighter color. It confines its attacks to the leaves and fruit, seldom attacking the twigs or branches.

The red scale of Florida, *C. aonidum*, is similar in appearance to the red scale of California, but the waxen cover is heavier and darker, usually reddish-brown or almost black with a whitish spot in the center. It is of little importance as an enemy of citrus trees, but is often a serious pest in greenhouses.

The Purple Scale (*Lepidosaphes becki*).—In general appearance this scale is very much like the oyster-shell scale that occurs on the apple trees. It attacks all parts of the trees, the leaves, branches, trunk and fruit frequently becoming entirely covered by the pest. It may cause the leaves or fruit to drop, or may even kill part of the tree, but it seldom kills the entire tree and so is not as serious a pest as the red scale. It occurs in destructive numbers throughout the citrus regions of Florida and the Gulf states and in certain sections of California. The female insect occupies only the anterior portion of the scale, the posterior portion being full of eggs and growing to meet the requirements as more eggs are produced. The young, soon after hatching, make their way from beneath the protecting scale, settle on the plant, and begin secreting the waxy substance that is to form their scale-like covering. It is toward the destruction of these younger scales that the orchardist must direct his attention, for the old insects are so well protected that it is difficult to kill them with any ordinary

spray or even by fumigation, nor will the fumigation affect the eggs. On badly infested trees it is usually necessary to give two treatments, the second about six weeks or two months later than the first, in order that the young which hatch after the first treatment may be killed. The dosage used in fumigating for the purple scale is one-fourth to one-third stronger than that used for the red scale.

FIG. 216.—Purple scale, *Lepidosaphes becki*. (Much enlarged; after Quayle, photo by Doane.)

Glover's Scale (*Lepidosaphes gloveri*).—The waxen scale of this insect resembles that of the purple scale, but is longer and narrower and less curved, hence it is often known as the long scale. It is a serious pest in Florida and the Gulf region, but has never become a pest in California. The life history and habits are much the same as those of the purple scale, and the remedies to be used are the same.

The Chaff Scale (*Parlatoria pergandi*).—The scales covering the females of this species are whitish, rounded or oval, with the molted skin close to one margin. The scale of the male is similar, but more elongate. They are usually found on the trunk and branches of the tree, but may also occur on the

fruit. The insect is destructive to citrus trees in Florida and the other Gulf states, but does not occur in California. It is very often found as a pest in greenhouses in many sections of the United States. When the scales occur on parts of the tree that can readily be reached with sprays they may be comparatively easily controlled by spraying with kerosene emulsion; otherwise, fumigation should be resorted to.

The Mealy-bug (*Pseudococcus citri*).—This insect is one of those kinds of *Coccidæ* that are unprotected by any scaly covering. The body is covered with a mealy or flocculent waxy secretion which, on the sides, takes the form of short waxy filaments. The two posterior filaments are two or three times as long as those on the sides. The insects are active during all the stages of their development until the female begins to secrete the loose, fluffy, cottony mass that serves to protect the eggs. The females may begin laying eggs when they are only five or six weeks old, and as each female will lay from three to four hundred eggs the number of individuals in a colony increases very rapidly. They may attack any part of the tree, but are usualy found in protected places, such as the base of the leaves, in the navel of the orange, or in places where the leaves or the fruit touch each other or some other object. These insects secrete considerable honey-dew, which is so very sticky that it takes much washing and brushing to remove it and the smutty fungus that grows on it from the fruit. Aside from the cost of the labor required to clean the fruit, this washing is undesirable because it affects the keeping qualities of the oranges and lemons.

FIG. 217.—Mealy-bug, *Pseudococcus citri*. (Greatly enlarged; after Quayle, photo by Doane.)

On account of their habit of hiding away in protected places, and because the cottony secretion that covers them is so hard

to penetrate, mealy-bugs are among the most dreaded pests in the orange and lemon orchards. Any of the sprays used at ordinary strength will leave many of them unharmed. A strong carbolic acid spray, made as suggested on page 417 and applied under a very high pressure, is the most efficient remedy yet found. Two or three or even more applications are often necessary before the insects can all be destroyed. Fumiga-

FIG. 218.—Mealy-bugs, *Pseudococcus citri*, on lemons. (Reduced; after Quayle, photo by Doane.)

tion as ordinarily used on citrus trees does not kill nearly all of the mealy-bugs, and for this reason has not proved as satisfactory as some of the sprays.

The mealy-bugs are attacked by several parasites and predaceous insects. The ladybird-beetles are particularly important in the control of this pest. The larvæ of one of these little beetles, *Cryptolæmus montrouzieri*, is covered with cottony tufts making it look very much like the mealy-bug

as it feeds among them. The larvæ of lace-wing flies and syrphus-flies also destroy many mealy-bugs.

The Cottony-cushion Scale (*Icerya purchasi*).—This insect was at one time the most serious pest of the citrus fruits in California where it destroyed many groves of citrus trees and

FIG. 219.—Cottony-cushion scale, *Icerya purchasi*, on orange tree. A few young are seen on the white egg sacs. (About natural size; after Quayle, photo by Doane.)

many ornamental plants. It has not appeared in destructive numbers in other parts of the United States. It was introduced into California from Australia about 1868, and within ten years had become very abundant and destructive, particularly in the southern part of the state. For some years the orange and lemon growers fought against it unsuccessfully.

Finally an entomologist was sent to Australia to study the pest in its native home and see if some natural enemy could not be found that would help to control it. Among other things that he sent back were colonies of the small ladybird-beetle now commonly known as the Australian ladybird, *Novius* (*Vedalia*) *cardinalis*, and within a remarkably short time this little beetle, both the larvæ and adults of which feed exclusively upon this scale, had so reduced the numbers of the pest that it was practically under control, and since that time the cottony-cushion scale has not been regarded as a serious pest. As soon as it appears in considerable numbers on any trees or plants some of the twigs or branches are cut off and sent to the State Horticultural Commissioner who in return sends out a small colony of the ladybird-beetles, if he finds that they are not already present among the specimens that are sent in. The large cottony egg sac of the female scale is longitudinally ribbed or fluted, and is a conspicuous object that is not likely to be mistaken for any other insect. The young are sometimes found on the leaves where they are easily recognized by the light cottony secretion and the large glass-like filaments that project from parts of the body. As the ladybird-beetles keep it so well in control it is rarely necessary to take any other measures to combat it.

Florida Wax-scale (*Ceroplastes floridensis*).—Although this insect seldom appears in great numbers on the orange or lemon trees, its striking appearance, when it is present at all, at once attracts attention to it and sometimes occasions considerable needless alarm. The young, which are seen on citrus trees more commonly than the adults, are covered with a white waxy secretion that radiates from the center so that the very young insect looks like a small oval white star. As the insect grows older the waxy covering becomes more or less distinctly separated into six or eight plates. The color is white with a pinkish tinge.

The Barnacle-scale (*C. cirripediformis*), looks somewhat like the preceding but is much larger and the waxy plates are more distinctly marked, each plate being mottled with grayish or light brown. As these insects rarely become at

all abundant it is seldom necessary to use any methods of control.

The Orange Thrips (*Euthrips citri*).—Within the last few years certain thrips have been doing considerable damage to the oranges in some parts of California. They usually work around the stem or depressions in the skin, making distinct whitish marks which, while not affecting the edible qualities of the fruit, seriously affect its market value, as such fruit cannot be graded as first class. The insects themselves are very minute, and are seldom noticed unless looked for very carefully. Spraying is the most satisfactory means of control. The sulphur-lime spray (see page 415) is the one most commonly used. It is necessary to use great care to reach all parts of the tree, and a high pressure is essential. There are other species of thrips that attack the orange, but their habits are the same and they yield to the same methods of control.

There are several other orange pests, such as Fuller's rose beetle, *Aramigus fulleri*, and the diabrotica beetle, *Diabrotica soror*, which feed on the leaves, doing particular damage to young shoots or to new grafts. The red and silver mites are referred to on page 213. The larvæ of certain moths attack the fruit and sometimes the leaves also, but these are usually of little importance.

The Mexican Orange Maggot (*Trypeta ludens*).—This insect has not yet established itself in the United States. It is, however, a serious pest of oranges in Mexico, and there is always a possibility of its gaining an entrance into this country in spite of the strict quarantine which is established against it. The larvæ, or maggots, feed in the pulp of the orange. When fully developed the larvæ enter the ground and pupate. The adult fly is yellowish in color, and has transparent wings marked with brownish bands.

CHAPTER XXXIV

INSECTS INJURIOUS TO VINEYARDS AND BERRIES

The small fruits have their insect enemies no less than the orchard fruits. Grapes, currants, berries, all have a constant struggle against insect pests, and call for our help in no uncertain tones. A quarter of a century ago the enormously valuable vineyards of France seemed to be on the point of total destruction from the insidious attacks of a minute soft-bodied delicate-winged aphid, the grape phylloxera, that carried on most of its deadly work underground and hence was hardly visible to the appalled vineyardists. And later, in the extensive vineyards of California a similar tale of destruction began to be told. The French government offered a great reward to any one who should devise an effective remedy for the pest, and scores of entomologists gave their whole time to the study of the life of the insect. Finally it was found that certain American wild grapes had developed a natural resistance or immunity to the attacks of the pest, and grape-growing was revolutionized by the adoption of the practice of grafting the valuable but delicate wine grape kinds on to the strong resistant wild roots. As the kind of fruit is determined by the graft and not by the stock this combination has proved the saving of the great vine industry of Europe and California.

Among the other grape pests are several kinds of beetles, the adults of which eat the leaves while their larvæ attack the roots, leaf-hoppers which take sap from the leaves and tendrils by means of their sharp little piercing and sucking beak, and the larvæ of certain small moths which eat both leaves and the grapes themselves.

Among the more important enemies of raspberries and blackberries are the active, strong-jawed larvæ of certain clear-winged moths (*Sesiidæ*) and certain beetles. These are variously called cane-borers, crown-borers and root-borers because

they mine the plants in these various parts of it. Scale-insects and slugs (larvæ of saw-flies) also do much damage.

Currants and gooseberries suffer from cane-borers, slugs, aphids and scale-insects, and from the effective girdling operations of a saw-fly that attacks the stems. Certain flies lay their eggs in the berries, and the hatching larvæ burrow in and feed on the pulp and seeds

Strawberries have an unusual number of insect enemies, including weevils, aphids and the boring larvæ of various moths and beetles.

For all these various pests remedies have to be devised with special care and ingenuity because of the tenderness of the plants and the fact that it is the berries themselves which are so often attacked and which, of course, cannot be poisoned. Careful pruning of partly infested plants and the complete cutting out and burning of more seriously attacked plants are largely resorted to by berry growers. However, arsenical sprays and emulsions of whale-oil soap and kerosene have their place in the fighting, as well as a number of special remedies applicable to the particular conditions under which berries are grown.

Students in any locality will have no difficulty in getting personally acquainted with some, at least, of the most important of the grape and berry pests described in the following paragraphs. For accounts of others, government and state bulletins, horticultural books and manuals of injurious insects may be referred to.

Grapes

The Grape-vine Phylloxera (*Phylloxera vastatrix*).—The insect referred to in the first paragraph of this chapter is a small brownish plant-louse or aphid, which is commonly called by its generic name, phylloxera. It may occur in four different forms. During the fall there appears a sexual generation which lays the winter eggs under the rough bark of the vine. These hatch early in the spring, and some of the young aphids crawl out to the leaves where they produce small but conspicuous reddish galls. This leaf feeding form rarely occurs on the

European varieties of grapes, and probably does not occur at all in California. Most of the young which hatch from the winter eggs crawl down to the roots, where their feeding causes small cancerous swellings or galls. Generation after generation of wingless individuals may be produced on the roots without any winged or sexual forms appearing, so that the whole root system may soon become badly infested. As the at-

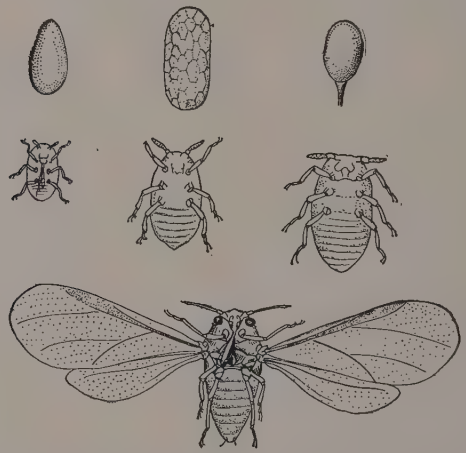

FIG. 220.—The grape phylloxera, *Phylloxera vastatrix*. In the upper left-hand corner an egg from which a male has issued, next an egg from which a female has issued; in upper right-hand corner, winter egg; at left-hand of middle row, a just-hatched young, next a male (note absence of mouth-parts); at right end of middle row, female; lower figure, winged form. (Much enlarged; after Ritter and Rübsaamen.)

tacked roots soon decay, the vitality of the vine is seriously affected and it usually dies within a short time. Sometimes, during the summer, a winged generation of females may appear. These make their way to the surface, fly to other plants and lay eggs there of two sizes. The smaller of these eggs produce the males and the larger the females of the sexual generation that lays the winter eggs.

No satisfactory remedies for controlling the pest in badly attacked vineyards have yet been found. Carbon bisulphide is sometimes introduced into the ground around the vines and many of the root-inhabiting aphids thus destroyed. Flooding has been resorted to in some regions, but such methods are either too expensive or are possible only in certain localities. When any of the vines are found to be unthrifty or dying, the roots should be examined carefully and, if the insect is found, all of the vines in the affected portion of the vineyard should be dug out and burned.

But the principal remedy for the phylloxera is the replanting of the vineyard on "resistant" roots. The pest is a native of America, and the wild grapes of this country have come to be naturally immune, or resistant, to the attacks of the insect. Grafting the European cultivated varieties on to the wild or only slightly modified American varieties is therefore an effective means of escaping the ravages of the pest.

Phylloxera was first made known in New York in 1853, and was soon discovered to be well scattered over the wild vines in the eastern United States. It was introduced into France about 1863, and increased with such rapidity that in twenty years it had destroyed more than one-third of all the vineyards of that country and had affected most of the others. It was introduced into California, where French varieties of grapes are largely grown, about 1874, and by 1900 many thousands of acres of vineyards had been destroyed. The vineyards of both Europe and California are now chiefly planted on resistant roots.

The Grape-root Worm (*Fidia viticida*).—The adult of this insect is a chestnut-brown beetle that appears on the vines about the close of the blooming season and begins feeding on the leaves. The series of cell-like holes or chain-like markings which it makes in the leaves are usually the first thing to attract the attention of the grower to the fact that these little pests are in his vineyard. The young larvæ which hatch from the eggs, that are deposited on the inner bark or in crevices of the vine, make their way into the ground and begin feeding on the roots. If they are abundant they may destroy many of the

smaller rootlets and may even injure the larger roots by eating off the bark. They lie dormant during the winter, and come near the surface early in the spring to pupate.

Deep cultivation late in the fall or early in the spring will destroy many of the larvæ and pupæ. A thorough spraying with arsenate of lead as soon as the beetles appear will destroy many of them, but a second spraying may be necessary a little later.

The Imported Grape-root Worm (*Adoxus vitis*), which occurs in California, has habits similar to the eastern species just described, and yields to the same treatment.

The Grape-vine Flea-beetles (*Haltica* spp.).—These are small, shining, green or dark blue beetles, characterized by their strongly developed hind legs which enable them to leap for considerable distances. The rose-chafer, *Macrodactylus subspinosus*, slender bodied and with long slender spiny legs, is another beetle that feeds on the foliage of the grape. In spraying for these various beetles the work must be done early, and it is often advisable to add glucose or molasses to the arsenate of lead (see page 415.)

The Grape-berry Moth (*Polychrosis viteana*), and the grape curculio, *Craponius inæqualis*, the larvæ of both of which feed on the foliage but do more damage by attacking the fruits, may be controlled by similar arsenical sprays.

The Grape Leaf-hopper (*Typhlocyba comes*).—This is a very widely distributed pest of the vines, and has come to be known by many common names, such as leaf-hopper, vine-hopper, vine-thrips or thrips, but as it is not a thrips at all, and as there are several other kinds of leaf-hoppers, it is better to call it the grape leaf-hopper. The adults are about one-eighth of an inch long, with the body and wings prettily marked with red or yellowish bands or spots. The over-wintering adults appear on the vines as soon as the buds open, and a little later lay their eggs beneath the epidermis of the underside of the leaf. The young are small, whitish, wingless insects with conspicuous red eyes, but become more and more like the adult with each molt. In some regions there is only one generation each year, but in other places there may be a partial or even a full second

generation. Adults hibernate in leaves or rubbish in the vineyard or along the fences or in near-by fields or meadows, and if such places are burned over during late fall or winter these hibernating adults may be destroyed.

When the insects attack the vines they may be more or less successfully controlled by spraying with some contact insecticide, such as whale-oil soap, kerosene emulsion, or resin spray (see page 417). An undershot nozzle must be used and great care taken to reach the underside of all the leaves. In California and other places where the vines are pruned back close to the main trunk each year, a hopper cage made by fastening fine wire screen, such as mosquito netting, over a frame may often be used with success. One side of the cage is left open and the bottom is made of a shallow tray with a U-shaped opening so that the cage may be pushed over the vine. The sides of the tray are smeared with crude oil so that the hoppers that fly from the vine when it is jarred are caught and killed in this material. When the vines are not pruned back, of course, this cage cannot be used. In such places sticky shields against which the leaf-hoppers are likely to jump when two men are carrying them on opposite sides of the vines, may catch and destroy large numbers of these pests.

FIG. 221.—Grape leaf-hoppers, at left *Typhlocyba vulnerata*, on right *T. comes*. (Much enlarged; after Forbes.)

RASPBERRIES AND BLACKBERRIES

The most serious pests of raspberries and blackberries are the borers that attack the canes. The raspberry root-borer, *Bembecia marginata*, also called the raspberry crown-borer, usually attacks the plant below the surface of the ground, sometimes girdling and killing it, but it may sometimes leave the roots and bore into the canes. The adult insects are beautiful clear-winged moths related to the peach-tree borer and the

currant-borers. The affected plants should be dug up and burned.

The Raspberry Cane-borer (*Oberea bimaculata*), the adult of which is a slender cylindrical beetle about one-half an inch long with antennæ about as long as the body, and the red-necked cane-borer, *Agrilus ruficollis*, the larvæ of a flat blackish or bronze-colored beetle with a red prothorax, both attack the canes of raspberries and blackberries. The larvæ of a fly that looks very much like a small house-fly also often destroy many of the new shoots.

FIG. 222.—Rose scale, *Aulacaspis rosæ*, on blackberry bush. (About natural size.)

In all these cases affected canes should be cut out and destroyed as soon as noticed.

Scale-insects.—Among the scale-insects which often attack the raspberry and blackberry vines, the rose-scale, *Aulacaspis rosæ*, is perhaps the most common. Attention is usually attracted to the presence of this insect by the white elongate scales of the males which often occur in such numbers as to make the canes look as if they had been whitewashed. The scale of the female is circular and somewhat darker.

The badly infested canes should be cut out and the others sprayed with the sulphur-lime wash during the winter.

Such leaf-feeding insects as the raspberry saw-fly, *Monophadnoides rubi*, and the raspberry Byturus, *Byturus unicolor*, may be controlled by spraying with arsenate of lead, if the application is made before the berries form. If the slug-like larvæ of saw-flies appear later, white hellebore may be sprayed or dusted on the plants. A little greenish or brownish mite, *Bryobia pratensis*, referred to on page 212, often occurs in destructive numbers on the raspberry leaves causing them to turn yellow and fall. Thorough sprayings or dustings with sulphur will usually control this mite.

Currants and Gooseberries

As with the raspberries and blackberries the cane-borers are the most important enemies of the currant and gooseberry bushes.

The Imported Currant-borer (*Ægeria tipuliformis*).—In appearance and habits this insect is much like the raspberry root-borer, but it works in the canes above the ground and not in the crown or roots. The eggs are laid in the axils of the leaves or on the currant canes, the larvæ boring into the canes as soon as they are hatched. During the winter the half-grown larvæ may be found in the center of the cane at the bottom of the burrow where they have been working. Early in the spring they commence to work again, pupating in May. The adult moths issue in June.

Fig. 223.—Imported currant-borer, *Ægeria tipuliformis*, adult. (About natural size.)

The leaves of the affected canes are lighter or yellowish in color, thus enabling one to detect and prune out the affected parts of the bush. All dead or affected wood should be cut out and destroyed as early as possible.

The Currant-stem Girdler (*Janus integer*).—This is a small, slender, shining black saw-fly that girdles the currant canes just above the point where she lays her eggs.

As the first indication of the presence of the pest is the dying tips that have been girdled, nothing can be done to check the damage that season, but if the affected stalks are cut off three or four inches below where they were girdled the larvæ, which are lying in the stalks, may be destroyed. If the pruning is left until winter time the cut should be made eight or nine inches below the dead end of the cane.

The Currant Saw-flies (*Pteronus ribesi* and *Gymnonychus appendiculatus*).—The larvæ of these saw-flies, which feed on the foliage, and any other leaf-feeding larvæ may be controlled by

spraying with arsenate of lead while there is no fruit on the bushes. At other times white hellebore should be dusted or sprayed over the plants.

The Currant Aphis (*Myzus ribis*).—In the spring or early summer the leaves of the currant bushes, and less frequently the gooseberry bushes, become more or less blistered and swollen and curled. The distorted parts are usually conspicuously red in color and soon attract attention. Examination will reveal colonies of small yellowish-green aphids on the underside of the leaves.

When only a few of the leaves are affected they should be picked off and destroyed. Spraying with kerosene emulsion or whale-oil soap or tobacco extract is effective if care is taken to reach the aphids before they have become well protected by the curling of the leaves. If the bushes are sprayed during the winter with sulphur-lime solution many of the eggs will be destroyed.

Scale-insects.—Several different species of scale-insects, the most important of which is the San Jose scale (see page 445), often attack the currant and gooseberry bushes and sometimes prove very destructive. The best remedy is to prune out the parts that are badly infested and spray the rest with sulphur-lime solution during the winter.

The Yellow Currant-fly (*Epochra canadensis*).—This fly is about the size of the house-fly, but the body is more slender and the wings are longer and narrower. The body and legs are pale yellow or brownish and the wings are marked with brownish cross bands. This insect passes the winter in the pupal stage in the ground or in rubbish below the bushes. The flies issue early in the spring and the females deposit their eggs in the berries just underneath the skin. The larvæ feed upon the pulp and seeds, and when full grown they leave the berries, which have dropped to the ground, and enter the ground to pupate. These fallen berries should, if possible, be destroyed before the larvæ leave them. If chickens are allowed to run under the bushes they will pick up many of the larvæ and pupæ. An effective but rather expensive way to save the crop of berries is to cover the entire bush with mosquito

netting taking care to tie it carefully around the bottom. If this is done just after the berries have formed, and before the flies appear, none of the berries can become infested.

A radical remedy is to destroy all of the fruit while it is quite small before any of the larvæ have had a chance to pupate. Thus by the loss of one crop all the flies in the garden will be destroyed, and reinfestation can only come from a neighbor's field. As the flies do not often fly far from the bushes this infestation will come but slowly.

FIG. 224.—Yellow currant-fly, *Epochra canadensis*, laying eggs on currants (Somewhat enlarged; photo by Paine.)

The Dark Currant-fly (*Rhagoletis ribicola*).—This fly is not as well known as the preceding species, but in the state of Washington and other places it is often very abundant and destructive. The adult is only about half as large as a house-fly. The body is shining black, the thorax marked by four narrow yellow lines and a conspicuous yellow spot. The wings are marked with four broad, brown cross bands, the outer pair of which are united anteriorly. The habits are similar to those of the preceding species, and the control measures the same.

Strawberries

The Strawberry Crown-borer (*Tyloderma fragariæ*).—The white grub-like larvæ of this beetle often cause the death of many plants by boring into the crown and eating out a large cavity. The dark-colored adult is about one-fifth of an inch long, and belongs to the group of snout beetles, having the head produced into a conspicuous blunt snout. The beetles pass the

Fig. 225.—Larvæ of strawberry crown-moth, *Sesia rutilans*, in crown of strawberry plant. (Somewhat reduced.)

winter in the soil, emerging in the spring to lay their eggs on the plants. All dead or weakened plants should be dug out and destroyed as soon as noticed. As soon as a bed becomes badly infested it should be plowed up and a new one planted elsewhere, care being taken to use young plants that contain no eggs or larvæ of this pest. As the beetles cannot fly the new bed will not be readily infested.

The Strawberry Crown-moth (*Sesia rutilans*).—On the Pacific Coast the strawberry crown-borer does not occur, but in its stead is another pest that works in much the same way and is even more destructive. This is called the strawberry crown-moth. The moths are a beautiful steel-blue or black. The adults lay their eggs on the crown of the plant early in the summer, and as the larvæ get older and larger they bore deeper and deeper into the crown, sometimes penetrating the larger roots. They may feed on the plants all winter, changing to the pupæ early in the summer.

The control measures suggested for the preceding species should be used in fighting this insect. Care must be taken to remove all of the crown and the large roots, or the larvæ will be left in the ground.

The Strawberry Weevil (*Anthonomus signatus*).—These little snout beetles appear in the strawberry patch early in the spring and gnaw small holes through the outer crust of the nearly mature buds where they deposit their eggs. They then cut the stem so that the bud soon falls to the ground. Where this pest is bad, only enough of the staminate varieties of vines should be grown to insure good fertilization, as the larvæ feed on the pollen of these plants. It may even prove profitable in some instances to plant early blooming staminate varieties in places where the beetles may readily gain access to them, and then destroy the plants after the beetles have laid all their eggs and before the adults of the next generation issue. Clean culture is important in order that the beetles may have few places in which to hibernate.

Strawberry Root-worms.—The larvæ of three or more species of beetles may be found on the roots of the strawberries, sometimes entering the crown also. The adult beetles are leaf feeders, and may be controlled by spraying with arsenate of lead. Where the roots are badly infested they should be dug out and burned.

The Strawberry Root-louse (*Aphis forbesi*).—Early in the spring a few small greenish aphids may be found on the underside of the strawberry leaves. Late in April or early in June ants begin to appear on the vines in considerable numbers,

and soon after this, if the roots of the plants are examined, the aphids will be found there also. The ants have carried the aphids from their nests to the roots, where they continue to care for them, taking them to new plants when the old plants die or become overcrowded. During the summer winged generations of the aphids appear, and thus distribute the species over wider areas. Late in the fall the winged sexual generation occurs, and the eggs are laid on the underside of the leaves, where they remain until they hatch in the following spring.

Little can be done to control the aphids on the roots of the plants. If the bed is badly infested the vines should be lightly covered with straw early in the spring and the whole area burned over. This will burn all the leaves and stems and destroy all the aphids as well as many other insects. A quick, hot fire will not seriously injure the plants. Care should be taken in selecting plants for transplanting to see that there are no eggs on the leaves nor aphids on the roots.

CHAPTER XXXV

INSECTS INJURIOUS TO GARDEN TRUCK

Only the market gardener and those who have tried to raise a few vegetables in their own kitchen gardens realize how many and how vexing are the insect pests of garden truck. The annual value of the truck crops in the United States is estimated to be more than three hundred million dollars, and yet each year the insects take about one-fifth of the vegetable crops, causing a loss, therefore, of more than sixty million dollars.

The garden pests, like those of the orchards and grain fields, are various in kind and life-history and in the manner in which they work their injuries. Leaf-eating beetles are especially numerous and serious in their attacks. The black and yellow striped Colorado potato-beetle, the active, leaping, little flea-beetles and the spotted and striped Diabroticas are conspicuous and familiar examples of these leaf-eaters. The caterpillars of various moths and butterflies also strip or mutilate the leaves of many vegetables. Cut-worms and army-worms are notorious pests of this kind. The naked green cabbage-worm, which is the larva of a dainty white butterfly imported from Europe half a century ago, is an especially serious caterpillar enemy of cabbages and other cruciferous garden plants. Several species of aphids often occur in sufficient numbers to do serious damage to peas, beets, cabbages and other vegetables. Squash-bugs, the harlequin cabbage-bugs, certain leaf-hoppers and other sucking bugs of the order *Hemiptera* take a heavy toll of plant sap from many garden plants.

The remedies for garden pests have to be, like those for the pests of vineyards and berries, especially devised to fit the particular conditions of vegetable growing. Not many kinds of garden truck can be sprayed with arsenical poisons, although some, of course, notably potato plants, can. Such simple

but often sufficient means as hand-picking and trapping can be effectually used, especially in smaller gardens. Clean cultivation and the destroying of all hiding places for over-wintering insects are great helps in the struggle.

Various special remedies are described in the accounts, which follow, of a few of the more important of the garden truck pests.

Potatoes

The Colorado Potato-beetle (*Leptinotarsa decemlineata*).—This beetle is in many regions the best known of all the garden pests. Its black and yellowish striped wings make it a

Fig. 226.—Colorado potato-beetle, *Leptinotarsa decemlineata*, and its larva. (About twice natural size.)

conspicuous object on the vines, and the results of its work are all too evident. It furnishes a good example of the way in which an insect once regarded as harmless may, by a slight change in its habits, become of very great economic importance. Originally it fed on various common weeds, especially the Colorado thistle, *Solanum rostratum*, in Colorado and other Rocky Mountain states. When potatoes (another species of *Solanum*) began to be planted in the region where the beetle occurred it found them more to its liking, and with the abundance of food that could be had with little or no effort, it so increased in numbers and spread so rapidly that it soon

became a most formidable foe, whose destructive work was checked only when we learned to use Paris green.

The beetles pass the winter in the ground, appearing in the spring as soon as the potatoes begin to grow. When the insects are abundant they may entirely destroy the young plants. The eggs are laid on the leaves, and the larvæ, which appear a little later, also attack the plants. There may be two or even three generations during the year. The insect has many enemies, the most important of which are certain tachina-flies, which lay their eggs on the larvæ, and certain predaceous insects which feed on the eggs or larvæ. In small patches the beetles, larvæ and eggs may be gathered from the vines and destroyed. Larger areas should be sprayed with Paris green or arsenate of lead, most growers now preferring the latter. It is used at the rate of three to five pounds to fifty gallons of water, the stronger spray being used for the beetles, the weaker for the larvæ.

Flea-beetles (*Epitrix* spp).—There are several species of flea-beetles that occur in the garden, attacking almost all kinds of plants. These are all small dark beetles that leap quickly when disturbed. They pass the winter in leaves or rubbish in the garden or along the fences, and early in the spring attack the young plants as soon as they appear above the ground. Particular damage may be done to potatoes by the minute whitish larvæ which sometimes feed on the tubers, making discolored little holes in them that detract from their market value.

If the plants are thoroughly sprayed very early with arsenate of lead most of the beetles may be destroyed. Bordeaux mixture seems to act as a repellent, so it is often worth while to use it and lead arsenate combined. When the tubers are infested by the larvæ they should be dug up as soon as they are mature and exposed to the sun for a few hours before storing.

Potato Stalk-borer (*Trichobaris trinotata*).—This is a small whitish grub that bores into the potato stalks, weakening or entirely destroying them. The pupa is formed in the vine near the surface of the ground, and the small grayish snout beetle, which issues a little later, remains there all winter. This suggests an efficient remedy. The vines should be raked up

and burned as soon as the potatoes are dug. These beetles feed on several different kinds of weeds so that any weeds in and near the garden should also be destroyed.

There is also another borer, the larva of the moth *Papaipema nitella*, that attacks potato stalks as well as tomatoes, corn, and many other plants. The larvæ pupate in the lower part of the stalk; therefore if the old vines and weeds are destroyed early in the fall this pest will usually not become troublesome.

The Potato Tuber-worm (*Phthorimæa operculella*).—For a long while this has been the most serious pest of potatoes in California. In the southern states it is a common tobacco pest, and has recently been reported as injuring potatoes there also. The moth issues early in the spring and lays her eggs on the young potato plants. The larvæ bore into the stalks, often killing them, but most damage is done when they make their way into the ground and attack the tubers, boring irregular channels in them and soon rendering the potatoes unfit for use. Several generations may occur each season, the moths of the later broods laying their eggs on the tubers when opportunity offers.

When plants are found to be wilting on account of the presence of these larvæ in the stalks they should be cut and destroyed to prevent infestation by later broods. The field and adjoining lands should be kept free of nightshade and other related plants as this insect feeds on these also. The potatoes should be exposed as little as possible, both before and after digging, so that the moth may not have an opportunity to lay her eggs on them. If stored potatoes are found to be badly infested they may be fumigated with carbon bisulphide. Four or more treatments at short intervals may be necessary before all of the larvæ are destroyed.

Peas and Beans

The Pea-weevil (*Bruchus pisorum*).—This common and widespread pest has made it impracticable to grow peas on a large scale in many regions. Some parts of Canada and some

of the northern states are comparatively free from the pest, and so furnish most of the seed that is used. The adults, which are small, grayish, snouted beetles, appear on the vines while the peas are in blossom, and lay their eggs on the young pods. The larvæ enter and feed on the peas, finally pupating in them. In the northern regions they remain in the seed until it is planted the following spring. In other places they leave the peas in the fall.

As there is only one generation a year, and as this species does not breed in dry peas, it is often worth while to hold the seed in bins or sacks until all of the adults have issued. Or the

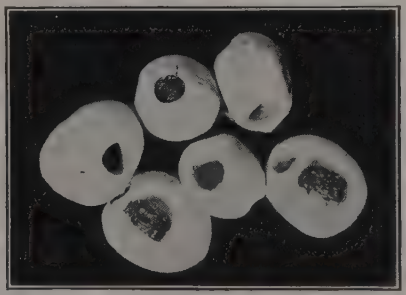

FIG. 227.—Pea-weevils, *Bruchus pisorum*, and infested peas. (About twice natural size.)

seed may be treated by heating or scalding or fumigating with carbon bisulphide.

The Bean-weevil (*Bruchus obtectus*).—This is the most common of three or four species of bean-weevils that occur in some parts of the United States. The adults are only about one-eighth of an inch long, dark-colored and short-snouted. Several larvæ or bettles may be found in one bean, and they continue to breed in the stored product throughout the year. All infested beans should be fumigated with carbon bisulphide as soon as possible. If the seed is thrown lightly into water most of the infested beans will float. By destroying these one can avoid planting infested seed.

The Pea Aphis (*Macrosiphum pisi*).—This large green aphis sometimes appears on the peas in such numbers as to weaken very much or even to kill the plants. The insects pass the winter on clover and vetches, sometimes doing considerable injury to these plants. They are usually fairly well controlled by natural enemies and fungus diseases, but it is sometimes necessary to resort to spraying in order to save the crop. Whale-oil soap or some of the tobacco washes may be used. Considerable force must be used in applying the spray. It is sometimes practicable to brush the aphids from the vines and destroy them by covering them with soil. Clover and peas should not be planted close together.

The Bean Thrips (*Heliothrips fasciatus*).—In many places on the Pacific coast this is the most serious pest of the peas and beans. It also does a great deal of damage to tomatoes, potatoes, alfalfa and many other cultivated and wild plants. The black-bodied little insect, with its four narrow, hair-fringed wings, is so small that it rarely attracts attention even when present in great numbers, and its presence is usually not suspected until the leaves of the plant begin to turn yellowish and dry up because the sap has been sucked out. There are six or seven generations during the year. The young are wingless and whitish, often with reddish markings on the sides of the body.

Because the insect feeds more commonly on the underside of the leaves, and on account of the nature of the crops that it infests, it is rarely practicable to control this pest by spraying. We must depend, then, upon the natural enemies of the thrips, and clean culture methods, for control. As this thrips feeds on many weeds, particularly on wild lettuce, these should be kept out of the garden and nearby fields.

Cabbage

The Imported Cabbage-worm (*Pontia rapæ*).—This is the most common of a number of butterfly and moth larvæ that feed on cabbage. Before this species was introduced into America, more than fifty years ago, the larvæ of some of our native butterflies belonging to the same genus were often

abundant in gardens, but they did not bore into the head of the cabbage as the invader does, and so were not such serious pests. Because it breeds more prolifically and feeds earlier and later in the season the imported species has almost or quite driven the others from the garden. The familiar white cabbage-butterflies, with their black-tipped fore wings, appear early in the spring and lay their eggs on almost any available

FIG. 228.—The imported cabbage-butterfly, *Pontia rapæ;* male above, female below. (Natural size.)

food. In the south the adults may be found at all times of the year. The female has two black spots in the disc of each fore wing, the male only one. Both sexes have a spot on the anterior margin of the hind wing. The larvæ are velvety green with a faint yellowish line above and yellowish spots on the sides. The pupæ, or chrysalids, are usually found on the underside of leaves, on rocks, fences or other objects. The insect usually passes the winter in the field in the pupal stage.

Minute hymenopterous parasites and other enemies aid in controlling this pest, but it is sometimes necessary to spray with arsenate of lead, two or three pounds to thirty gallons of water. Where the insect is troublesome the spraying should be done early and repeated as often as is necessary to protect the plants until the heads form. If the fields are well cleaned many of the over-wintering pupæ will be destroyed. The same measures should be used for the control of any of the other leaf-feeding larvæ, and for the flea-beetles and others that often attack the cabbage.

The Harlequin Cabbage-bug (*Murgantia histrionica*).—These bright-colored cabbage-bugs, or calico-backs, or fire-bugs, are often found feeding on the cabbage, where they do much damage, particularly to young plants, by sucking the sap from them. The adults, which hibernate in rubbish, become active very early in the spring. This has suggested the use of trap-crops such as kale, which may be planted early so that the bugs may feed on it and be destroyed there by spraying with kerosene before the cabbages are planted. The young, or nymphs, may be destroyed on the cabbage by spraying with strong kerosene emulsion or whale-oil soap. If a field is kept clean during the winter, so that the insects will have few places in which to hibernate, they will usually not become destructively abundant.

The Cabbage Aphis (*Aphis brassicæ*).—These little greenish aphids are nearly always more or less abundant on the cabbage, but usually little damage is done except to the young plants. Any of the contact insecticides, such as kerosene emulsion, or whale-oil soap, or tobacco extract, will destroy the aphids if it is applied with considerable force. Again, clean culture is the most successful means for combatting this garden pest, for if all of the refuse is destroyed in the field the over-wintering insects will perish

The Cabbage-maggot (*Pegomyia brassicæ*).—The roots of cabbage, cauliflower and radishes are frequently tunneled by small whitish, footless maggots which are sometimes so numerous that they seriously weaken or kill the plant. The adults are small flies that look much like the common house-fly, but

they are less than one-fourth of an inch long. The flies lay their eggs on the plant close to the surface of the ground, or in the soil near the plant. The larvæ soon mine into the stalk or roots, where they feed for a few weeks, entering the soil again to pupate. There may be two or three generations during the summer.

After the larvæ have entered the plant but little can be done to control them. Most of them can be killed by pouring a teaspoonful of carbon bisulphide in a small hole four or five inches from the plant, but this is hardly practicable on a large scale. Control by cultural methods is more satisfactory. All the old plants and roots should be destroyed early in the fall, as many of the pupæ pass the winter in or around these. Fall plowing and crop rotation are to be recommended. Mustard and other cruciferous wild plants should not be allowed in or near the garden, as they also harbor this pest. If the cabbages are not planted until most of the flies have laid their eggs on some other plants they will escape serious injury. Seed beds should be protected so the plants will not become infected before they are transplanted. Some growers keep the fly from laying her eggs on the plant by protecting it with a collar of tarred felt paper which lies on the ground and surrounds the base of the plant. Gas tar and other repellents have been used with more or less success. Very early or very late radishes may escape infestation.

Beets

The Beet Leaf-hopper (*Eutettix tenella*).—In some of the western states where sugar beets are grown extensively a condition known as beet curly-leaf, or blight, has caused considerable loss, particularly in warm dry seasons. A few years ago it was discovered that this condition is caused by a very small whitish leaf-hopper that sucks the sap from the leaves. When the plants are badly infested the beets become stunted, or shrivel, and are of little or no value.

So far no practicable means of control has been found, but if the land is kept moist and other conditions made favorable for the plants they will be better able to withstand the loss

due to the insects' feeding. Spraying with contact insecticides has been suggested, but as the insects feed on the underside of the leaves it is difficult to reach them.

Web-worms.—There are three or more species of web-worms (caterpillars) that attack, and sometimes defoliate beets and other garden plants. They are called web-worms on account of their habit of spinning fine webs as they feed. The invaded plants may be killed outright, or only retarded in their development. The slender, greenish worms are marked with many small black spots and sometimes with lighter markings. When fully developed they enter the ground and spin long slender cocoons in which they pupate. The adult moths are greenish or brownish and have a wing expanse of about an inch.

They may be controlled by spraying with Paris green or arsenate of lead. If the field is plowed late in the fall many of the pupæ will be destroyed. As these worms feed on other plants, including many of the common weeds, it is evident that these should be kept out of the garden or fields.

The Beet Aphis (*Pemphigus betæ*).—Sometimes the beets in certain parts of the field are found to be much smaller than the average, and soft and spongy rather than firm as they should be. If such beets are taken from the ground they may be found to be covered with a mold-like substance which is really the flocculent excretion from many little plant-lice that are feeding there. As long as this insect fed on yarrow, door-mat weed, grasses, and other wild plants as it used to, it was, of course, of no economic importance, but as soon as beets began to be cultivated in the region where it occurred it found them more to its liking, and now in some regions many tons of beets are destroyed by it each year.

If this pest becomes abundant in a field it should be starved out by refraining from planting beets or other root crops there for two or three years.

Other Garden Insects

Cut-worms and Army-worms.—Most of the common dull grayish cut-worms (caterpillars of certain owlet-moths), hide

away in the ground or rubbish during the day and come forth at night to feed on any available vegetation. As they have a pernicious habit of cutting off small tender plants close to the surface of the ground, they may often do much damage, particularly in the garden. They are usually held in check by

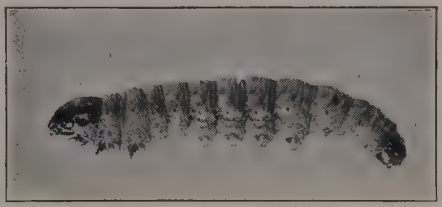

FIG. 229.—A cut-worm, species undetermined. (About natural size.)

their natural enemies, but sometimes they seem to get away from control and occur in such numbers that they destroy nearly every green thing in the affected regions. At such times some of the species will begin to migrate in great armies

FIG. 230.—Adult of army-worm, *Leucania unipuncta*. (About natural size.)

in search of food. They are then called army-worms, and their control becomes a matter of prime importance to the man whose field, orchard or garden lies in their path.

The methods used in fighting cut-worms must vary according to time, place and local conditions. No single remedy can be

given that will prove equally successful at all times and places. Remedies that are very effective under ordinary conditions often become wholly useless during a bad outbreak. Clean cultivation will materially lessen the number of larvæ that occur in a garden under ordinary circumstances. When the worms are abundant and marching, ditching is often resorted to, usually with very satisfactory results. Banding trees with tanglefoot or some similar substance is helpful in case the cut-worms are of the climbing sort. A very few in a garden may destroy many valuable plants, so it is often worth while to search for them in the ground around the plants, and destroy them. Poisoned baits may often be used with success. When they suddenly appear in great numbers in a field but little can be done to control them.

The Corn Ear-worm (*Heliothis obsoleta*).—This larva bores unsightly irregular channels on the ears of corn, doing particular damage to sweet corn. It is also a serious pest of cotton, feeding in and destroying the bolls; hence it is also known as the cotton boll-worm. Tomato fruit-worms and tobacco bud-worms are among some of the other names that are applied to this pest, which attacks almost all kinds of garden crops and many forage plants. The greenish-yellow adult moths appear early in the spring and lay their eggs on corn and other food plants. The larvæ feed about a month, and then enter the ground to pupate. There may be from two to five or six broods during the summer, the greatest number occurring in the south where the feeding season is longer.

In the garden about the only satisfactory means of control is hand picking. It is seldom practicable to spray. In the cornfield the time of planting should be so regulated that the corn will not be in silk when the moths are flying most abundantly. All infested land should be plowed late in the fall or during the winter, as this will destroy many of the over-wintering pupæ.

The Striped Cucumber-beetle (*Diabrotica vittata*).—These small, yellow, black-striped beetles attack many of the vines in the garden as soon as they are above the ground, and as they often occur in great numbers they may destroy most of the

young tender plants. The eggs are laid in the soil about the food plant, and the slender white larvæ feed on the roots, sometimes doing considerable damage there. As the adult hibernates in the ground or in rubbish in the field, all of the vines should be destroyed as soon as the crop is off. The most practicable method of protecting the young vines is to cover them with a screen that will keep the beetles away. Early squash or beans may be planted as trap-crops so that the insects will be attracted to these while the other vines are getting well started. Air-slaked lime, tobacco dust or other powders thoroughly dusted over the plants, afford some protection, especially if some untreated trap-crop is near-by.

FIG. 231.—The cucumber-beetle, *Diabrotica 12-punctata*. (Three times natural size.)

Squash-bug (*Anasa tristis*).—This rather large, flattened, blackish bug is often found sucking the sap from the leaves of various vegetables, but it is found most commonly on squash vines. The adults hibernate in the garden and appear early in the summer. The eggs are laid on the underside of the leaves. The wingless young or nymphs also feed on the leaves. In the south there may be two or even three generations during the year. The insects may be gathered and destroyed, and the egg masses may be easily crushed on the leaves. Shingles or boards or leaves placed on the ground near the plants make good hiding places for the adults, and if such traps are examined in the evening and early morning many of the bugs may be found and killed.

The Squash-vine Borer (*Melittia satyriniformis*).—Often the squash vines wilt and die because of the attacks of a whitish, black-headed larva that bores into them. Other vines may also suffer, but the late varieties of squash seem to suffer most. The borers may attack almost any part of the vine, but do most damage when they are working in the base, for they may then destroy the whole vine. The adult is one of the clear-winged moths (family *Sesiidæ*), looking somewhat like the

peach-tree borer. The eggs may be laid on any part of the plant. In the South there may be two generations each year. As the borers feed in the vine they cannot be reached by insecticides. A gummy exudation usually discloses the position of the larvæ, and it is sometimes worth while to slit the vine open and kill the pest. The vines should be burned as soon as the crop is gathered. Fall and winter plowing and crop rotation will help to control such insects as these.

The Onion-maggot (*Pegomyia ceparum*).—The roots and bulbs of onions are sometimes attacked by small white maggots that in appearance resemble the cabbage-maggot. The adults of the two species are closely related and can only be distinguished by close examination. The cultural methods suggested for controlling the cabbage-maggot are effective in dealing with this insect also.

The Tomato-worms, or Tobacco-worms, which are often serious pests on tomato vines are described on page 499.

CHAPTER XXXVI

INSECTS AFFECTING FIELD AND FORAGE CROPS

As the great field crops of the United States are its chief wealth, the insect pests that attack grains, cotton and grasses are the most important animal enemies of our material welfare. The annual losses from insect attacks on cereals amount to three hundred million dollars, on hay and forage crops to sixty-six million dollars and to cotton eighty-five million dollars. The annual losses to wheat and corn caused by the attacks of but two insects, the Hessian-fly and the chinch-bug, must amount to a hundred million dollars. Too much time and care, then, cannot be given to the study of the nature of the grain pests and to devising means of lessening their ravages. Because of the enormous supply of food furnished them by our great fields of growing grain, their numbers may become, without restraint, almost inconceivable. In fact, in the case of all the insect pests of fruits and crops it is our own fault, as it were, that has led them to become as dangerous to these crops as they are. We have, by our planting of great numbers of one kind of plant together, furnished the insects such bountiful supplies of food that their enormous increase in numbers is an inevitable result. It is this encouraged increase that constitutes the danger. The number of chinch-bug individuals that can live at one time in a growing cornfield of hundreds of acres is simply inconceivable. But as the increase of animals proceeds by geometrical ratio while the addition of new acres of food supply can increase only by arithmetical ratio, the insect numbers finally become more than the food supply can maintain without too much injury, and then the great losses begin.

The grain pests are of great variety of kind and habit. Aphids, and beetle and moth larvæ attack the roots. Biting

beetles and sucking bugs attack the leaves and stems. The minute whitish larvæ of small flies lie in the stems or leaf axils and drain the sap. Weevils ravage the stored grain. Cotton has its peculiar pests, one of which alone, the notorious cotton boll-weevil, that came into this country from Mexico only twenty years ago, has in the last decade caused an annual loss of not less than twenty-five million dollars.

Grasses and forage plants have an exceptionally wide range of insect enemies, and enemies that for the most part are very difficult to fight successfully in any inexpensive way. Most of their combating must be done by such general agricultural methods as crop rotation, or very deep or unusually late or early plowing, etc.

The few grain, cotton, and forage crop pests described in the following paragraphs comprise the ones of chief importance, but there are many others to be taken into account. Students should refer to sources of more inclusive and detailed information concerning these pests. The bulletins of the government and state bureaus of entomology are good sources for this information. Sanderson's "Insect Pests of Farm, Orchard and Garden," already mentioned, is a good recent manual.

Corn

The Western Corn-root Worm (*Diabrotica longicornis*).—This is a slender larva, or grub, that bores into the roots of young corn and seriously interferes with its development. Sometimes these larvæ will destroy the greater part of the root system so that the plant either dies, or is easily blown over by the wind, or, if it lives, is unproductive. The adult is a small bluish-green, leaf-eating beetle about one-third of an inch long. The eggs are laid in the ground in the fall near the roots of the corn and do not hatch until the following spring. As the larvæ feed only on corn it is evident that a system of crop rotation will control the pest.

The Southern Corn-root Worm (*Diabrotica 12-punctata*).—The larva of this species is similar in appearance and habits to the one just described, but it has a wider range of food plants.

The wing-covers of the small bright-green beetle are marked with twelve black spots. The beetle feeds on the foliage of many garden and field plants, often doing considerable damage. On account of this wide range of food plants it is not as easily controlled as the preceding species, but crop rotation will still be of some value. Sometimes it is profitable to plant the corn so late that it will not come up until after the beetles have laid their eggs on other plants.

The Corn-root Web-worm (*Crambus caliginosellus*).—This is still another larva that attacks the roots and stalks of corn, sometimes killing so many of the young plants that the field must be reseeded. The yellowish or brownish little caterpillars, covered with a case made out of loose web and particles of dirt, are usually found feeding in the corn plant below the surface or close to the surface of the ground. The adults are small, white and yellowish "grass-moths," so called because they are so frequently seen flying from the grass when it is disturbed. When the moths are at rest the wings are folded close around the body. The larvæ of the second generation hibernate in their silken tubes, and are ready to begin feeding as soon as the plants begin to grow. As the larvæ live on the roots of grasses, corn that is planted on new land will suffer most. In well-cultivated fields where crop rotation and late fall or early spring plowing is the practice the injury is usually not so great.

The Larger Corn-stalk Borer (*Diatræ zeacolella*).—This insect belongs to the same family of moths as the preceding species but it is larger. The larvæ live in the stalk of the corn, often weakening it so that it is easily broken by the wind. In the fall the caterpillars of the second generation bore deep into the tap-root and there pass the winter, pupating early in the spring. If the old stalks and butts are dragged together and burned most of these over-wintering larvæ will be killed. Again, crop rotation is recommended as the best remedy.

The Bill-bugs (*Sphenophorus* spp.).—There are several species of snout beetles, or weevils, that injure corn and other field crops by attacking the stalk and roots. They are usually injurious in both the larval and adult stages, and are hard to

control. One species, at least, passes the winter in the corn stubble, and can be killed by burning the stubble. They will all be less injurious in fields where root crops are rotated with corn or wheat crops.

The Corn-root Aphis (*Aphis maidi-radicis*).—Sometimes the corn roots are badly infested with little greenish plant-lice that suck the sap from the plant. The life-history of this insect is especially interesting as it shows the close relation that ants and plant-lice sometimes bear to each other. In the fall the little brown field ants, *Lasius brunneus*, gather the eggs that have been laid by the aphids in the ground, and store them in their nests. Here they are cared for until they begin to hatch in the following spring. The ants then carry the young plant-lice to the roots of grasses or weeds that grow in the cornfield and carefully tend them there, moving them to new plants when the old ones become overcrowded. When the corn is planted many of the aphids are transferred to the roots of the corn, and, as they increase in numbers very rapidly, much damage may be done in some fields. Because the ants tend them with such care and receive in return the honey-dew that is secreted by them these aphids are often called "ant-cows."

If grasses or weeds are not allowed to grow in the field during the early spring most of the aphids will starve before the corn sprouts.

The Corn Ear-worm, which frequently does much damage in the field, has been discussed on page 486.

Wheat

Chinch-bugs (*Blissus leucopterus*).—The adult chinch-bugs are only about one-fifth of an inch long. The body is dark-colored, and the whitish wings, which lie folded over the back, are each marked by a dark triangular spot. The very young, often called "red-bugs," have no wings, but these gradually develop as the insect passes through its successive molts. Because of their habit of assembling in such great numbers on the stems of wheat, corn and many other field crops, the chinch-bugs are often the worst pest the farmer has to

contend with. The insects hibernate in old corn stalks, dead leaves, clumps of grass or other sheltered places in the field or roadside. As soon as the grasses or grains begin to grow they begin feeding on them and lay their eggs, from which the first brood of young soon issues. They may do serious injury to the wheat or other small grains before the crops ripen. About the time the wheat is ready for harvest the chinch-bugs migrate to oats or young corn. Fortunately, they do not fly when making these migrations, but crawl slowly from field to field. The eggs from which the second brood are to hatch are laid in the corn. The young of this brood become mature late in the fall and seek out suitable places to hibernate. If corn is not available the whole season may be passed on grasses.

FIG. 232.—The chinch-bug, *Blissus leucopterus*. (Nine times natural size.)

Many years ago it was discovered that the chinch-bugs were attacked by a fungus disease that sometimes very effectively controlled them. When infected bugs are taken into the laboratory and placed in boxes with healthy bugs, the latter soon become infected. These infected bugs may then be sent into the fields and placed on badly infested plants. In this way the disease rapidly spreads, and when the climatic conditions are right it soon destroys most of the chinch-bugs in the field. But this method of control has not been wholly satisfactory because in cool and dry weather the disease does not spread fast enough.

Clean culture is of prime importance. If the adult bugs that are hibernating in the fields or in grasses by the roadside and fences are destroyed by burning, there will be no injury in the following spring. When the insects are migrating from the wheat to the corn they may be effectively checked by barriers of dust or coal tar. The dust barrier is made by plowing and thoroughly pulverizing a narrow strip of ground

and then making a deep furrow in it across which the chinch-bugs cannot pass. The furrow must be kept in good condition by frequent cleaning or dragging. In wet weather it will be necessary to resort to a barrier made by a narrow line of coal-tar or some similar substance placed across the path of the invaders. Such barriers require constant care and attention during the ten days or two weeks that the bugs are migrating. Sometimes when the chinch bugs have gained an entrance into a cornfield those that have massed on the first few rows of corn can be destroyed by a blast torch or by spraying with kerosene emulsion.

The Hessian-fly (*Mayetiola destructor*).—Probably about 10 per cent. of the wheat crop is destroyed annually by the Hessian-fly and in some regions the loss may reach 40 or 50 per cent. in bad years. The adult is a very small blackish fly with a pair of delicate wings that are provided with very few veins. The eggs are usually laid on the leaves, and the larvæ make their way toward the base of the stem where, protected by the leaf sheath, they begin sucking the juice from the plant. The puparium in which the pupal stage is passed looks so like a flax seed that the pupal stage is usually referred to as the "flax-seed stage." There may be one to four generations a year, according to the region and climatic conditions, but the early spring and late fall broods are most destructive. The flies that issue late in the fall lay their eggs on the young winter wheat, and the pupal, or flax-seed, stage is reached before cold weather comes. The adults issue from these pupæ early the next spring.

FIG. 233.—The Hessian-fly, *Mayetiola destructor*, adult male. (Much enlarged; after Marlatt.)

The best method of control is to refrain from planting the wheat in the fall until the flies have laid their eggs elsewhere. Only a close study of the fly and the weather conditions that control its time of issuing in the fall will enable one to

choose the right date for sowing. After conducting long series of experiments the United States Bureau of Entomology has suggested the following dates as safe for sowing wheat in average seasons: in northern Michigan soon after the first of September; in southern Michigan and northern Ohio, about September 20; in southern Ohio, after the first week in October; in Kentucky and Tennessee, October 10 to 20; in Georgia and South Carolina, October 20 to November 15. The exact time will also depend upon altitude as well as latitude. Crop rotation, thorough cultivation, clean culture and the use of good fertilizers are all important in regions where the Hessian-fly is a bad pest. No varieties of wheat thus far found are wholly exempt from the attacks of the fly but some, on account of their habit of growth, withstand the injury better than others.

The larvæ of certain other flies may also often be found working in the wheat in much the same way as the Hessian-fly, but they rarely occur in sufficient numbers to do serious damage.

The Wheat Joint-worm (*Isosoma tritici*).—The joint-worms occur in the stems of the wheat causing them to swell slightly and become hard and woody so that the grain is not well nourished. The adults are small black insects belonging to the family *Chalcididæ*, nearly all the other members of which are parasitic. Crop rotation is the best means of control. Infected straw and stubble should be burned before the adult insects, which are overwintering in such places, issue.

The Wheat Straw-worm (*Isosoma grandi*).—This insect is closely related to the preceding species, but has somewhat different habits. Many of the members of the spring brood are wingless and look much like small ants. The eggs are laid on the young wheat, and the larvæ frequently destroy the whole plant by eating out the crown. The adults of the next generation are larger and provided with wings so that they may fly considerable distances. The young that hatch from the eggs of this brood work in much the same way as the wheat joint-worms. They pass the winter in the pupal stage in the straw.

The control measures are the same as for the wheat joint-worm.

The Grain-aphis, or Green-bug (*Toxoptera graminum*).—This little green plant-louse sometimes seriously injures young wheat plants by sucking out the sap. They do most damage in the south, where the open winters often allow them to feed and reproduce during the whole year. In such instances they become so abundant on the winter wheat that whole crops may be ruined as early as March or April. As long as the temperature is above 56° F. the green-bugs are held in check by a minute wasp-like parasite, *Lysiphlebus testaceipes*, and it is only during the winter time, when it is warm enough for the pest to breed but too cold for the parasite, that the plant-lice become destructively abundant. Oats are the favorite food of these aphids, and they seldom do much damage in places where volunteer oats are not allowed to grow.

When small injured spots appear in the field late in the winter the green-bugs in such areas should be killed by spraying with kerosene emulsion, or by burning straw over them, or by plowing under the infected grain.

Stored Grain

Stored grains are often attacked by the larvæ of beetles or moths, and unless preventive measures are adopted much of the grain may be destroyed.

The Grain-weevil (*Calandra granaria*), **and the Rice-weevil** (*C. oryzæ*).—Weevils are usually the most common pests of stored grain. They are small beetles with long snouts, with which they puncture the grain, thus making a place where the egg may be inserted. The larvæ are short, thick, legless grubs that feed in the grain until ready to pupate. The beetles, too, feed on the grain, and as they increase in numbers very rapidly a slight infestation may soon assume serious proportions. Grain should be stored only in clean, tight bins. If this precaution is taken but little loss will be suffered on account of these pests. If, however, the grain becomes infested, it should be treated with carbon bisulphide, using about five pounds for every 1000 cubic feet, or even more if the room is not tight. Best results will be obtained if the temperature is 70° F. or higher. Dishes containing the liquid, or cotton or waste

saturated with it, should be placed on top of the grain. As the gas that comes from it is heavy it will sink and reach all parts of the bin. Remember that this gas is inflammable and explosive. If the grain in the bins can be heated to 120° F. all the weevils in all stages of development will be killed.

The Saw-toothed Grain-beetle (*Silvanus surinamensis*).—Unlike the weevils, which are somewhat cylindrical, this small grain-beetle is quite flat. It may easily be recognized by the serrate margins of the prothorax. The larvæ are long and slender and provided with six legs, enabling them to move about freely and thus injure several grains. The methods of control are the same as for the weevils.

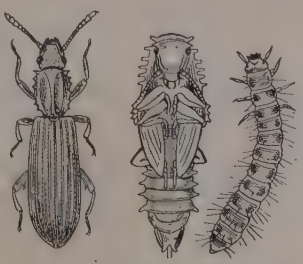

FIG. 234.—Adult, pupa, and larva, of the saw-toothed grain-beetle, *Silvanus surinamensis*. (Much enlarged; after Howard and Marlatt.)

The Angumois Grain-moth (*Sitotroga cerealella*).—In the south the grain-moth is even a worse pest than the weevils for it often occurs in almost incredible numbers and attacks wheat in the field as well as in the granaries. The moths fly from the storerooms while the wheat is heading, and lay their eggs on the grain. The larvæ make their way into the kernels and become full grown about the time the wheat is mature. Other generations follow, the members of each attacking the grain wherever it is found, in the field, in the stack, or in store-rooms. Corn is not attacked as often as wheat, but seed corn stored in barns may often be badly injured. The grain should be threshed as early as possible and stored in tight bins or good sacks. If it becomes infested while stored, it may be treated with carbon bisulphide. Cleanliness about the barns and particularly around the granaries is most essential. Badly infested grain may be fed to chickens or hogs.

The Mediterranean Flour-moth (*Ephestia kuehniella*).—Mills are sometimes overrun with the larvæ of a small grayish

moth. The larvæ spin little silken tubes which protect them while they are feeding in the flour or waste about the mill. When full grown they wander about in search of a suitable place to pupate, spinning a web wherever they go. It is this habit that renders them most injurious, for the infested flour and many parts of the mill become filled with the webs. This necessitates frequent and expensive stoppings of work in the infested mills. Great cleanliness about the mill is necessary. When the insect becomes troublesome the mill should be closed tightly and fumigated with hydrocyanic acid gas under the direction of some experienced person. If the temperature throughout the mill can be raised to about 120° F. and maintained there for a day, all moths, pupæ, larvæ and eggs will be killed.

Cotton

The Boll-weevil (*Anthonomus grandis*).—There are several important enemies of the cotton plants, but during the last few years the boll-weevil has become so important as to overshadow almost all the others. Indeed, one of these insects,

Fig. 235.—Boll-weevil, *Anthonomus grandis*. (Much enlarged.)

the cotton-worm, which was formerly looked upon as one of the worst enemies, is now regarded with some favor by many planters because it sometimes aids in controlling the weevil by stripping the late foliage from the plants and thus depriving the weevil of its food.

This small, brownish snout beetle is commonly known as the Mexican cotton boll-weevil because, like several other insect pests of the south, it came into the United States from Mexico.

The beetles attack only cotton. Those issuing from their winter hiding places early, feed on the foliage and lay their eggs on the unopened buds, or "squares," as soon as they commence to form. The larvæ hatching from these eggs feed for ten or twelve days, and usually cause the infested squares to fall to the ground. There may be four or five generations during the summer, the beetles attacking the older bolls as soon as the squares are no longer available. The adults of the last generation hibernate in old cotton plants or in rubbish in or near the fields. When they are hunting for suitable places in which to hibernate they may fly for considerable distances, and thus the distribution of the species is provided for.

The larvæ in many of the infested squares that drop to the ground will perish on the hot, unshaded soil. It is therefore advisable to plant the rows as far apart as practicable and to use varieties of cotton that produce little foliage in order that the sun may shine on the fallen squares. As the damage is usually worse on the late varieties the best of the early varieties should be selected in regions where there is danger of boll-weevil infestation. Any cultural methods that will strengthen the plant and aid in the early maturing of the bolls will materially increase the yield. As soon as the crop is gathered all the cotton stalks and all the rubbish in the field should be burned. This will kill many of the insects, and destroy the feeding and hibernating places of most of those that are left.

The Cotton Boll-worm, which is the same as the corn ear-worm, has been discussed on page 486. It is best controlled in the cotton field by plowing late in the fall, thus destroying the over-wintering pupæ. Early varieties of cotton should be planted, as it is the later broods of moths that lay their eggs on the cotton, the corn being preferred as long as it is young and available. Late planted corn in or near the cotton fields will sometimes keep the boll-worm away from the cotton.

Tobacco

Tobacco-worms, or Horn-worms.—The large greenish horn-worms (larvæ of sphinx- or hawk-moths) are probably the most

serious pests of tobacco in the United States. They feed on the green leaves, and, when abundant, may cause a loss of from 10 to 15 per cent. of the crop. Two species, somewhat similar in appearance and habits, are found throughout the tobacco growing regions. The northern tobacco-worm, *Phlegethontius quinquemaculata*, is more common north of the latitude of Washington, D. C., and the southern tobacco-worm, *P. sextata*, is the species usually destructive in the southern tobacco fields.

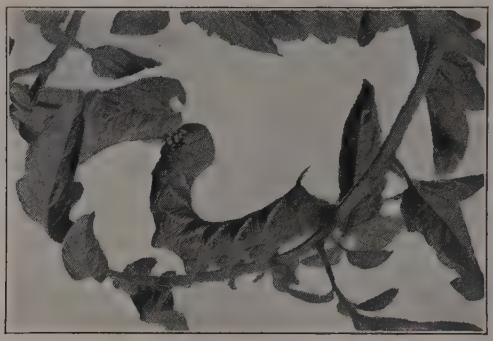

FIG. 236.—Tobacco-worm, larva of the hawk-moth, *Phlegethontius quinquemaculata*, feeding on tomato. (About 1/2 natural size.)

The adults, which are large grayish sphinx-moths, lay their eggs on the lower surface of the leaves. The larvæ feed on the leaves and become full grown in about three weeks. They are then three or four inches long and dark green in color with white stripes on the sides. On the northern species these white markings are V-shaped, while on the southern species they are simply oblique lines. On the last segment of the body is the conspicuous "horn," which has suggested the name "horn-worm." The larvæ burrow into the ground a few inches before changing to the brownish pupæ. In the pupal stage the proboscis of the forming moth is inclosed in a peculiar handle-like sheath. In some regions these pupæ are known as

"horn-blowers." During the summer the pupal stage lasts about three weeks, and there may be two or even three generations in the south.

The insect passes the winter in the pupal stage. Many of the pupæ can be destroyed by thorough plowing and harrowing. As the larvæ are usually easily detected on the plant, hand-picking is the common method of control where labor is cheap. Paris green dusted or sprayed over the plants has long been a favorite remedy, but as this sometimes burns the foliage, arsenate of lead is now more commonly used. From four to six pounds of arsenate of lead to 100 gallons of water are the proportions usually recommended.

These same horn-worms are often important enemies of tomatoes.

The Tobacco Flea-beetle (*Epitrix parvula*).—This small, black flea-beetle looks much like flea-beetles more commonly found on tomatoes, potatoes and other garden plants. Indeed, this species does not restrict itself to tobacco, but may often be found on other plants in the field and garden. The beetles feed on the foliage, and, when abundant, may do considerable damage, particularly to young plants. The slender, whitish larvæ usually feed on the roots of weeds, but they sometimes attack the roots of garden plants also. They pupate in the soil when fully developed. There are probably several generations each year.

If the field is kept free from weeds there will be less opportunity for the larvæ to find food. Where the beetles appear in destructive numbers the plants should be sprayed thoroughly with arsenate of lead, five or six pounds of the poison to 100 gallons of water. The tops of the young plants may be dipped into an even stronger solution of the poison just before they are set out if there is danger of the flea-beetles attacking them early.

The Tobacco Leaf-miner (*Phthorimæa operculella.*)—This little larva, which is only about half an inch long, lives between the upper and lower epidermis of the leaves causing them to split. This has suggested the popular name of "split-worm" for the pest. Sometimes the larvæ come to the surface and

wander about before entering the leaf in another place. If the leaves are well sprayed with arsenate of lead many of the larvæ will be poisoned as they attempt to eat their way into the leaf again. The adult insect is a small gravish moth with minute dark spots on the front wings.

The Cigarette-beetle (*Lasioderma serricorne*).—This minute brownish beetle, which is only about one-sixteenth of an inch long, and its whitish grub or larva, feed on dried tobacco whenever they can find it. They do serious damage to the stored dried leaves and to cigars and cigarettes after they have been manufactured. In warm factories the insect may breed throughout the year and increase in numbers very rapidly. As this pest lives and breeds in any kind of dried tobacco it is necessary to keep the factory clean and not allow fragments or dust to collect in out of the way places. Infested tobacco or tobacco products or infested factories may be fumigated with carbon bisulphide or with hydrocyanic gas.

There are several other insects that do more or less damage to tobacco, but most of them can be controlled by keeping the field and its immediate vicinity free from weeds, especially those weeds that are nearly related to the tobacco plant, or by spraying with arsenate of lead.

Grasses and Forage Plants

The Clover Root-borer (*Hylastinus obscurus*).—The roots of clover are often attacked by a short, thick, whitish larva that feeds in the tap root or the larger rootlets. The adult insect is a beetle only about one-eighth of an inch long and reddish-brown in color. The beetles hibernate in the infested plants, and early in the spring fly to new plants where they lay their eggs. Badly infested fields should be plowed up as soon as the crop is cut so that the roots may dry out and the larvæ starve before they are ready to pupate. This insect is seldom injurious in pastures.

The Alfalfa Weevil (*Phytonomus murinus*).—The alfalfa weevil has recently been introduced into some of the western states and threatens to become a serious pest. Both the larvæ

and adults feed on the foliage and sometimes on the stem of the plant also, so they are capable of doing much injury. The beetles are only a little over one-eighth of an inch long, dark brown, and are covered with short, thick, black and grayish hairs. The snout is short and curved.

Among the control measures that have been suggested are cutting the first growth when most of the eggs are on the plant, disking the field early in the spring and dragging the field with brush after the crop has been cut. Every effort is being made to prevent the spread of this pest.

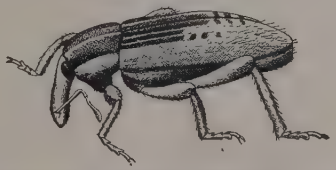

FIG. 237.—Alfalfa weevil, *Phytonomus murinus*. (Much enlarged.)

Grubs.—Grass and pasture lands are often badly infested with large white grubs which feed on the roots of the plants growing there. These may remain in the larval stage two or three years, but finally transform to pupæ from which issue the large, brown beetles known as May-beetles, or June-bugs. The beetles fly at night and are frequently attracted to lights. As these same insects are common pests of corn and of many other cultivated plants it is not well to let them become numerous in grass lands that are near cultivated fields. Deep plowing late in the fall will destroy or expose to the birds many of the larvæ and pupæ. Hogs turned into an infested pasture will root out and eat most of the grubs.

Wire-worms.—The long, cylindrical, hard, wire-worms have habits similar to the grubs just discussed. They may remain in the larval stage from three to five years and often do considerable damage to corn, wheat, potatoes and other field and garden crops. The adults are the well-known click-beetles, or snapping-beetles. Late fall or eary spring plowing, and crop rotation, are the control measures usually adopted.

Grasshoppers.—There are many species of grasshoppers that occur in fields or meadows in greater or less numbers every year. The Rocky Mountain locust, that lives permanently on the high plains of some of the Rocky Mountain states, was for many years the best known of these because of its great migrations into the Mississippi Valley where it destroyed all the vegetation to be found there. The last of these migrations was in 1877. The settling and consequent changed conditions of the regions in which this grasshopper breeds have put a stop to the great flights.

Grasshoppers lay their eggs in masses in the ground, and cover them over with a sticky fluid that forms a capsule-like covering when dry. Meadows and pastures or bare, dry, rather firm ground, are the places usually selected for egg-laying. The wingless young, or nymphs, that issue the following spring feed on grasses or any other available vegetation. When the food becomes scarce they may travel in great numbers as do the army worms, devouring every green thing in their path. However, they cannot travel far in this wingless stage, and even after acquiring their wings most kinds seldom fly far from their breeding grounds, and so are easily controlled. If the places where the eggs are deposited are plowed during the fall or early spring most of the eggs will be destroyed or buried so deep that the young cannot come to the surface when they hatch. It is sometimes practicable to burn over a field where the young occur in great numbers and thus destroy them before they migrate to cultivated fields. On hard smooth ground many may be killed by rolling with a heavy roller. When the nymphs are migrating a field may be protected by ditching as for the army worms (page 484). The poisoned mash (page 415) recommended for use against cutworms, may also be used with success against the grasshoppers. Various forms of hopper-dozers have been contrived for catching the wingless grasshoppers. The most common is a long, shallow pan or tray mounted on runners in which is placed a little water covered with kerosene or crude oil. Oil or coal tar may be used without the water. The back and ends are provided with walls about three feet high to prevent the grasshoppers from

jumping over it when the apparatus is pulled or pushed across the field.

Ordinarily the grasshoppers are pretty well controlled by their natural enemies, among the more important of which are birds, the larvæ of blister-beetles, tachina-flies and bee-flies, and a little red mite that attacks the nymphs and the eggs.

CHAPTER XXXVII

INSECTS INJURIOUS TO FOREST AND SHADE TREES

Since the attention of the American people has been called to the need of preserving and caring for the forests of our land, and the government has established forest reservations in all those states still containing extensive wooded areas, the study of the insect pests of forest trees has made considerable progress. Although in European countries, especially Germany, the study of forest insects has been the most notable part of the economic entomological work, it has not been so in America. But forest preservation is a much older science in Europe than with us, where, indeed, it is a very recent thing.

The insect enemies of forest trees are many, and often very serious in their ravages. Especially in the great pine forests are the insects a constant menace, and too often a menace realized. Fire is the only other forest enemy as dangerous as the insects. And the danger of fire, because less insidious and difficult to appreciate, is being much more rapidly lessened by vigilant care and effective methods of prevention than is the less obvious but more widespread and continuous danger from insect attack.

Forest entomologists estimate the annual forest loss from insect pests at one hundred million dollars. Yet the injuries to shade and ornamental trees are likely to have, in the eyes of most of us, an importance that outweighs that of the forest losses. No money value can satisfactorily be assigned to a row of stately elms along a street in town or village, nor to a single well-placed, splendid old oak in a dooryard. We shall give, therefore, special attention in this brief chapter to the insect enemies of shade trees and to the means of fighting them. This is the more fitting, also, as forest insects must be controlled rather by general forestry methods and the work of specially

trained forest rangers and caretakers than by the usual methods of the economic entomologist.

The few insects described in the following paragraphs are perhaps the most important of the commoner pests of shade trees, but there are many others of similar habits which may be found by keen-eyed and persevering students. The remedies for these others will be of the same general nature as those recommended for the insects described, although modifications of them may need to be made to fit particular cases.

Government and state bulletins will give further and more detailed information about the pests briefly described here and also about others likely to be found on the trees.

The Gipsy-moth (*Porthetria dispar*).—One of the very worst of the many shade tree and woodland pests is the gipsy-moth,

FIG. 238.—Gipsy-moth, *Porthetria dispar*, adult female. (About 1/4 larger than natural size.)

which was introduced into this country from Europe about 1868. Fortunately it spreads slowly and as yet occurs only in the New England states. The federal government and the states concerned are now spending more than a million dollars a year in trying to control this pest. But in spite of all their efforts the insect is gradually widening the boundaries of the infested areas, and other localities may in time suffer from its ravages.

The brownish-yellow, slender-bodied, male moth flies readily, but fortunately the large, sluggish female cannot fly, although

she is provided with well developed wings. The female has the wings whitish, marked with small black spots and wavy lines. She lays her eggs on the trees, near-by fences or hedges or other convenient objects. The egg masses, which consist of 400 or 500 eggs covered over with yellowish hairs from the insect's body, remain over winter in these places. The young caterpillars, which issue early in May, at once begin feeding on any available foliage. They are covered with long hairs, and as they swing from the branches by fine silken threads they may be carried by winds for considerable distances, or they may drop on passing vehicles and be transported for some miles before they drop off. Thus new localities, not too far away, are easily

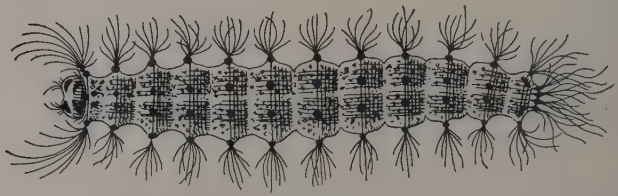

FIG. 239.—Gipsy-moth, *Porthetria dispar*, larva. (About 1/4 larger than natural size.)

infected. The full-grown dark-brown larvæ attain a length of about three inches, and attack practically all kinds of wild and cultivated trees and shrubs. A deciduous tree will often live even after three or four defoliations, but the coniferous trees die after one complete stripping.

In the orchard this pest may be fairly well controlled by painting the egg masses with creosote sometime during the winter, or by spraying the leaves with arsenate of lead as soon as the larvæ appear in the spring. In the woodlot control is much more difficult, and usually even impossible, although the same measures as recommended for the orchard may sometimes be practicable. As the very young larvæ do not feed on conifers these trees may be protected by clearing out all brush and deciduous trees. In its native home this insect is not such a serious pest because it is controlled by its natural enemies.

For several years the U. S. Bureau of Entomology has been introducing many of these parasitic and predaceous insects, hoping that some would prove to be efficient here. A measure of success has attended these efforts and it is quite possible that

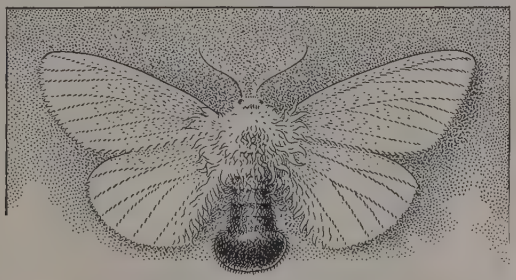

FIG. 240.—Brown-tail moth, *Euproctis chrysorrhœa*, adult. (About 1/4 larger than natural size.)

when enough of these natural enemies have been established in this country the pest may be overcome, and, in the future, kept in reasonable control.

The Brown-tail Moth (*Euproctis chrysorrhœa*).—Like the gipsy-moth the brown-tail was introduced from Europe, but

FIG. 241.—Brown-tail moth, *Euproctis chrysorrhœa*, larva. (About 1/4 larger than natural size.)

much more recently. It attacks orchard trees and almost all kinds of shade trees except the evergreens. The moths are snow-white, with a conspicuous brown tuft at the end of the abdomen. They fly by night, and are attracted by lights, so that shade trees and fruit trees in towns are usually first to

suffer from their attacks. The insects pass the winter as small larvæ that hibernate in a nest made of leaves and tips of twigs fastened together with silken webs. Some of the hairs of the full-grown larvæ cause severe irritation when they touch the human skin. This is regarded by many as the most serious phase of an outbreak of this pest. As yet the insect occurs

FIG. 242.—Tent of tent-caterpillar on a live-oak tree. (Reduced.)

only in some of the New England states, but it is constantly being introduced into other states on nursery stock, and unless great care is taken it may soon become established elsewhere.

The winter nests containing the young larvæ are conspicuous on the leafless trees, and should be pruned off and burned. Arsenate of lead, 4 pounds to 50 gallons of water, will kill most of

the young larvæ before they make their nests if the trees are sprayed as soon as the eggs are hatched in the late fall.

Tent-caterpillars and tussock-moths, which have been described in the chapter on orchard insects, and many other leaf-feeding larvæ, often do much damage to shade trees. A study of their habits and life history will usually reveal some vulnerable point and suggest the control measures to be adopted. Where arsenate of lead is used it is usually necessary to use 4 or 5 pounds to 50 gallons of water.

The Elm Leaf-beetle (*Galerucella luteola*).—Elm trees are attacked and seriously injured by many different insects. In many places the leaf-beetles are the most important of these pests. These beetles are about one-fourth of an inch long and greenish or yellowish marked with darker spots and lines. They hibernate in protected places during the winter and feed for awhile on the young leaves in the spring before they lay their eggs. The larvæ feed for two or three weeks before descending to the ground to pupate. There may be two generations each year.

Although it is difficult to spray trees as tall as elms often grow to be, without the use of special apparatus, yet it is possible to construct a spraying outfit that will enable the operator to reach easily all parts of the tree. Infested trees should be sprayed with arsenate of lead as soon as the beetles begin to feed in the spring, and again about two weeks later when the first larvæ hatch. Sometimes later sprayings may also be necessary.

Plant-lice and Scale-insects.—Many of the plant-lice that feed on the foliage of various shade trees, and the scale-insects that may attack any parts of the trees above the ground, can often be controlled by spraying with kerosene emulsion during the summer or, and usually better, with the sulphur-lime wash during the winter.

The Locust-borer (*Cyllene robiniæ*).—Locust trees are often attacked by borers which after a little while penetrate so far into the wood that they cannot be removed or killed. These borers are the larvæ of dark-brownish beetles which are about an inch and a half long and have eight or ten narrow golden

yellow stripes across the thorax and wing covers. Repeated attacks may kill the trees, and it is the safest policy to cut out and burn all infested trees in order that they may not serve as breeding places for new generations that will later attack sound trees.

The Carpenter-worm (*Prionoxystus robiniæ*).—The larvæ of a large, grayish, night-flying moth have come to be known as "carpenter worms" because they work so readily in the wood

FIG. 243.—Elm leaves curled by elm aphis, *Schizoneura ulmi*. (Reduced.)

of many of our shade trees. For some months after hatching the larvæ burrow in the sapwood, and when several of them are at work in one tree they may kill it by girdling. As they grow older the larvæ bore into the solid wood, making large burrows in which they live for a year or two longer before they change to pupæ. As these borers are more apt to be found in trees that have the bark rough or scarred or wounded, care should be taken to keep the bark uninjured. The larvæ

in the burrows may be killed by injecting a little carbon bisulphide into the hole after the castings and exudations have been cleared from the entrance. The hole in the bark should then be filled with cement.

The Leopard-moth (*Zeuzera pyrina*).—The leopard-moths are beautiful white moths that have their bodies and wings marked with many black spots. The larvæ may be found in any part of the tree, but they more often attack the smaller limbs. As they work principally in the sapwood, the affected limbs are usually killed. The only satisfactory method of treatment is to cut out all the infested wood and burn it. It is easier and safer to sacrifice the whole tree if it is badly infested. The female moths do not fly readily, so the infestation does not spread rapidly except in places where the trees are very close together.

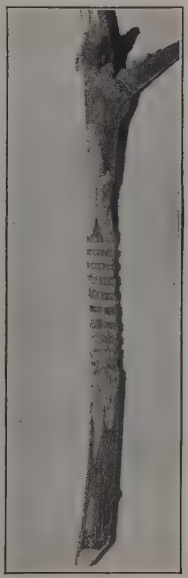

FIG. 244.—Work of oak twig-girdler, *Agrilus* sp. (About 2/3 natural size.)

The Oak-pruner (*Elaphidion villosum*).—When oak-pruner beetles occur in considerable numbers the trees are made unsightly by the dead branches which later fall to the ground. The damage is done by the larvæ, which bore in the twigs and finally cut them off. As the larvæ pupate in the fallen twigs they should be gathered and burned before the adult beetles issue. This insect attacks many kinds of shade trees, and sometimes may be injurious to certain fruit trees also.

On the Pacific Coast there is another smaller borer, *Agrilus politus*, that attacks and kills the small branches of the oak trees. As the twigs are killed, but not cut off, the tree soon becomes very ragged and unpleasing in appearance. Such infested twigs should be cut off some time during the winter.

Forest Insects

A certain amount of insect injury is occurring in almost every great forest all the time, while from time to time particular forests are devastated by the outbreaks of certain insects that kill practically all of the trees in the affected regions. In some instances these outbreaks have spread over 50,000 square miles,

Fig. 245.—Work of a bark-borer, *Phlœosinus cristatus*, on Monterey cypress. (Reduced.)

and trees that would have produced millions of feet of lumber have been destroyed. Each year there are lesser outbreaks when, although comparatively few trees may be killed, many are retarded in their growth or so distorted or injured that they make only second- or third-class lumber. Altogether the

annual loss to our forests from insect attacks must amount to many millions of dollars.

A great part of this injury is due to the work of the bark-beetles, belonging to the family *Ipidæ*. These are small, robust, blunt-headed beetles which burrow into the bark to lay their eggs, and whose larvæ burrow out through the live bark in all directions from the egg chambers. Of these bark-beetles the members of the genus *Dendroctonus* are the largest and the most important. The adult beetles bore into the bark until they reach the cambium where each species makes a characteristic kind of burrow. The larvæ also make characteristic chambers in the bark or on the surface of the wood so that one who is acquainted with their work can always tell from the nature of the borings just which species has been at work on a tree. The members of the genera *Ips*, *Scolytus*, and others also frequently do considerable damage. For a long while it was believed that nothing could be done to control the spread of these insects in the forests. But a study of their life-history suggested that many of them might be controlled by cutting out the infested trees and thus destroying the immature stages of the beetles before the adults issue to attack new trees. Experience has shown that this is practicable, and the Bureau of Entomology has agents in the principal forest regions to direct properly the work of cutting wherever the owners care to undertake it.

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